Sheet Metal Industries

The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

VOL. 38 : No. 405 JANUARY 1961 PRICE 2/6


GOOD PRODUCTS DEMAND A GOOD PRESS
BRITISH CLEARING Presses
Built by
VICKERS
help to produce High Quality Domestic Appliances
'DIMPLEX' Radiator
Made on 600 ton BRITISH CLEARING Press
This British Clearing Press installed in the second of two new factories built for Messrs. DIMPLEX LTD., at Southampton is helping their major development plan in fulfilling the large demand for 'Dimplex' products.
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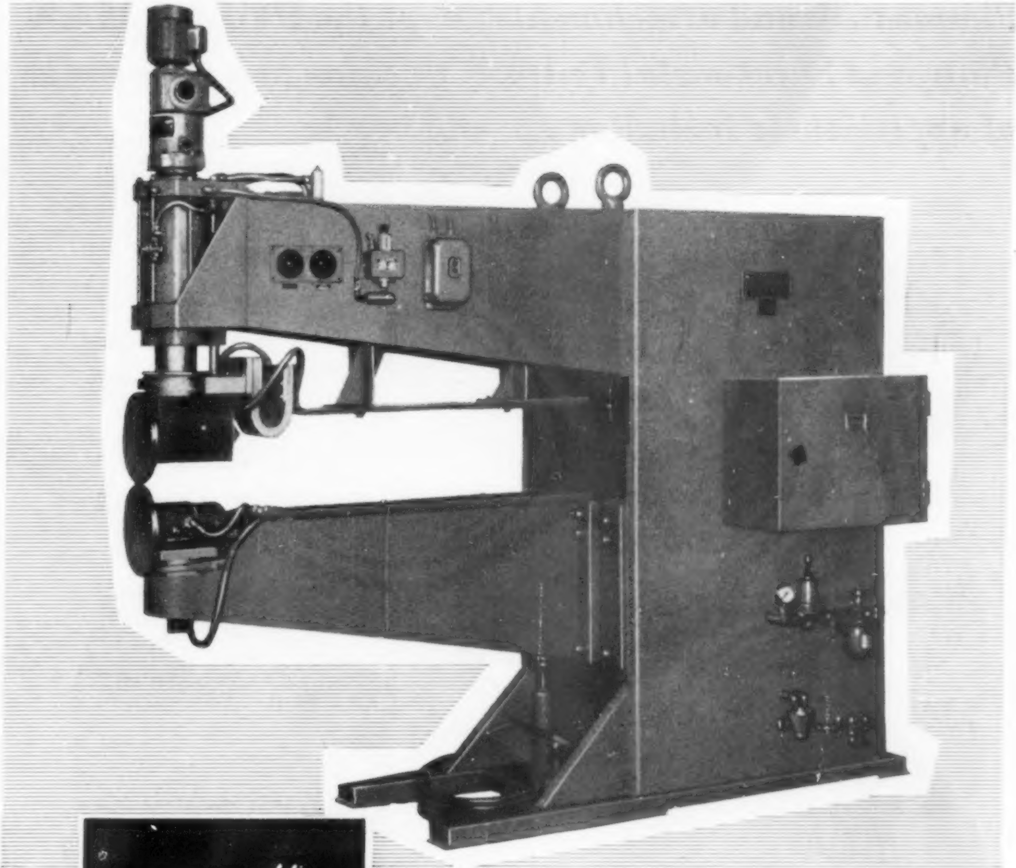


GOOD PRODUCTS DEMAND A GOOD PRESS
BRITISH CLEARING Presses
Built by
VICKERS
help to produce
High Quality
Domestic Appliances
B CMC CLEARING
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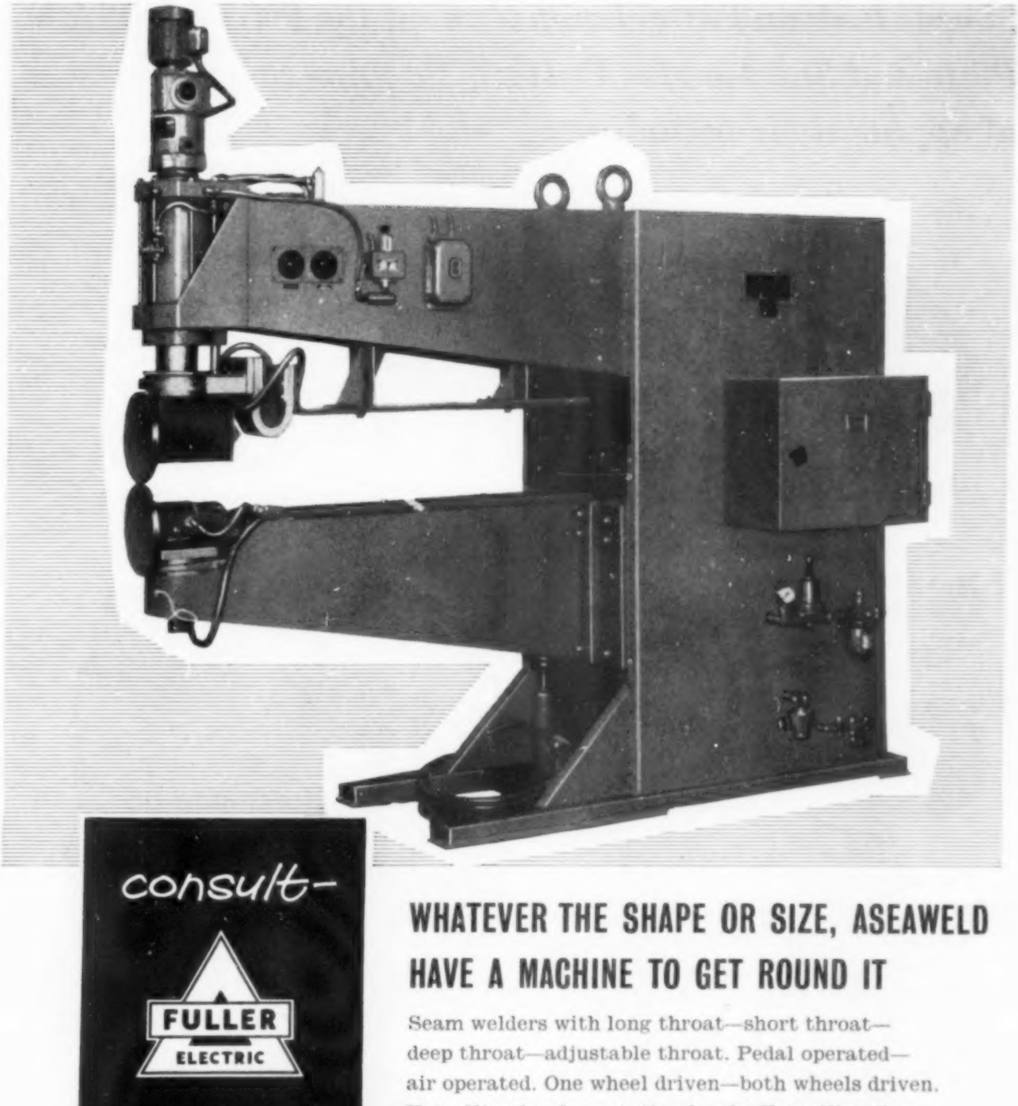

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A JOINT PROBLEM . . .
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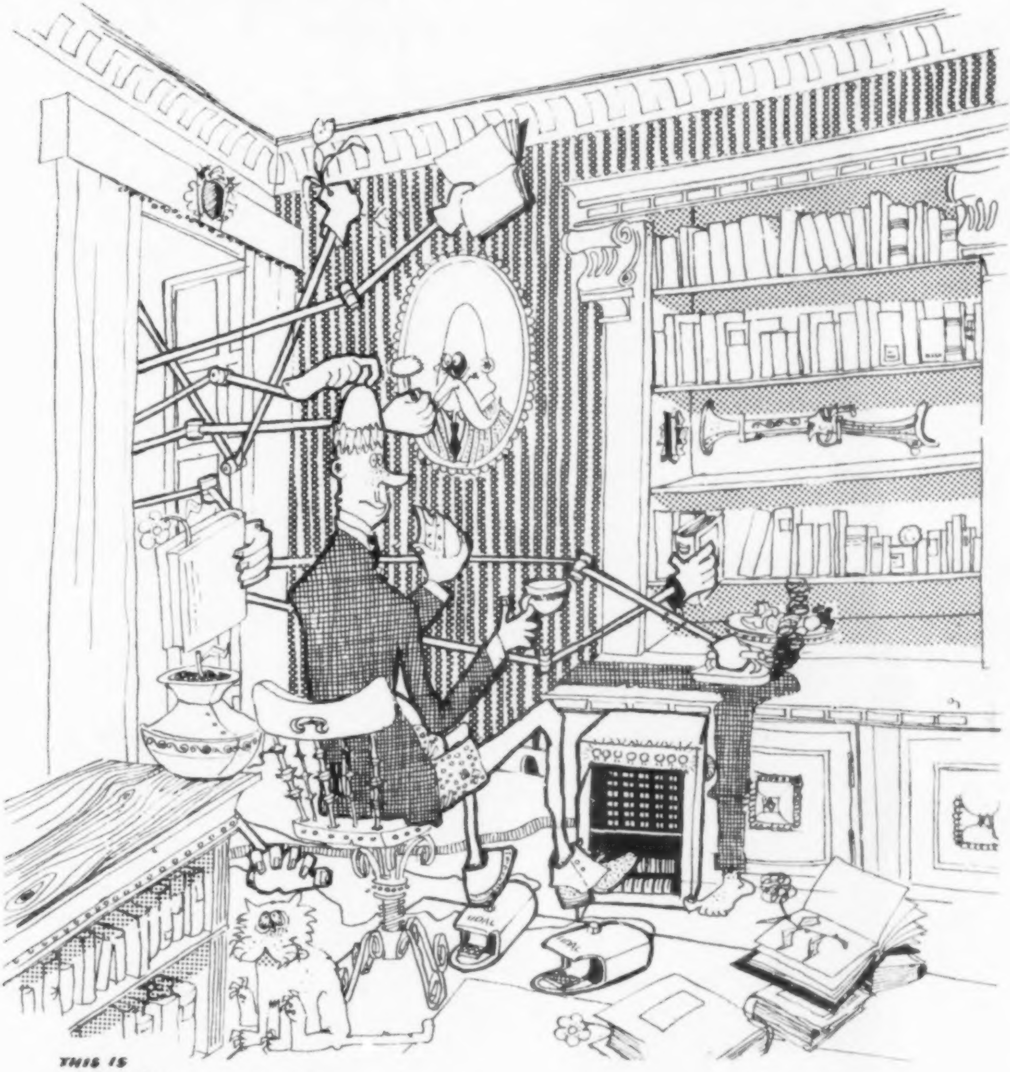

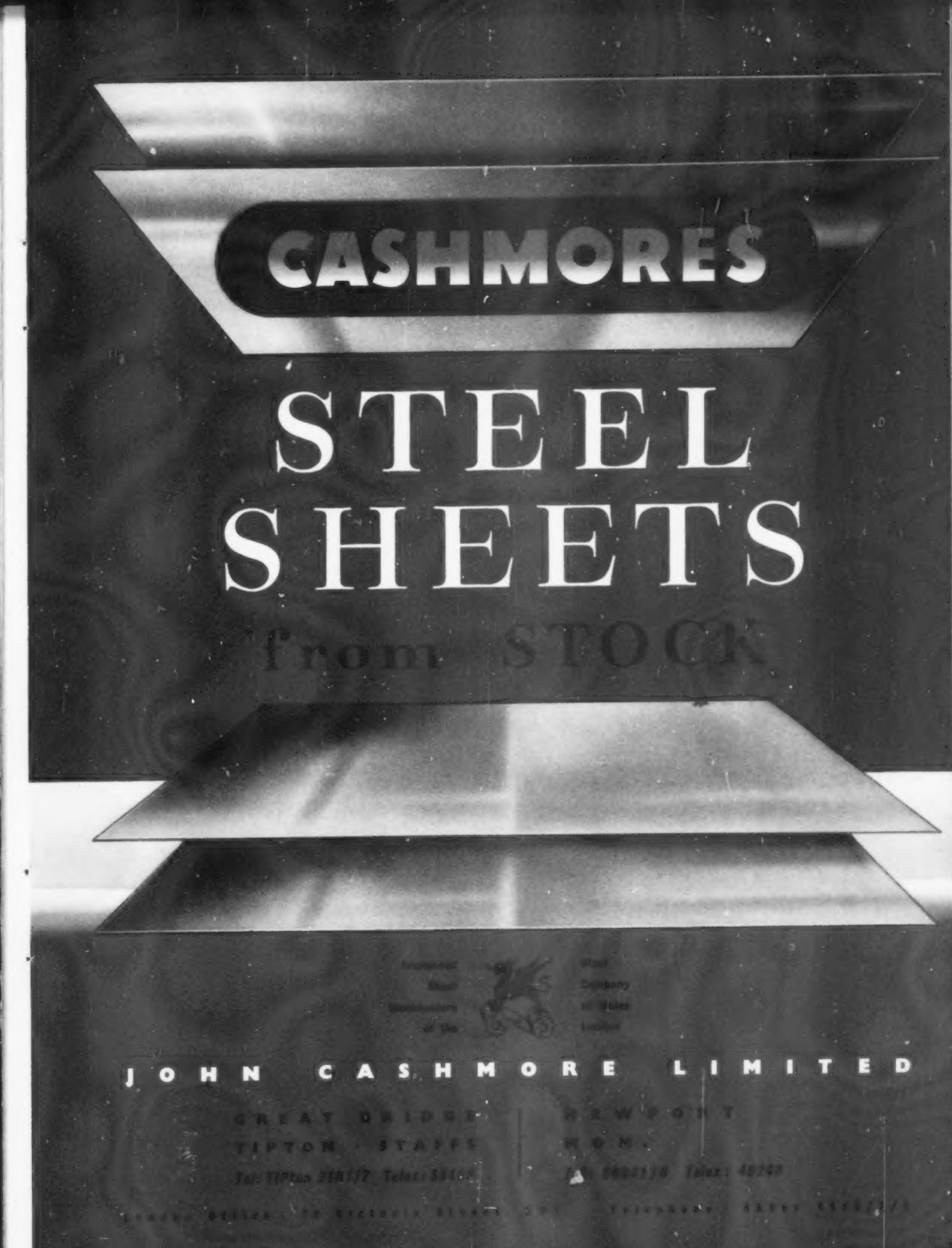
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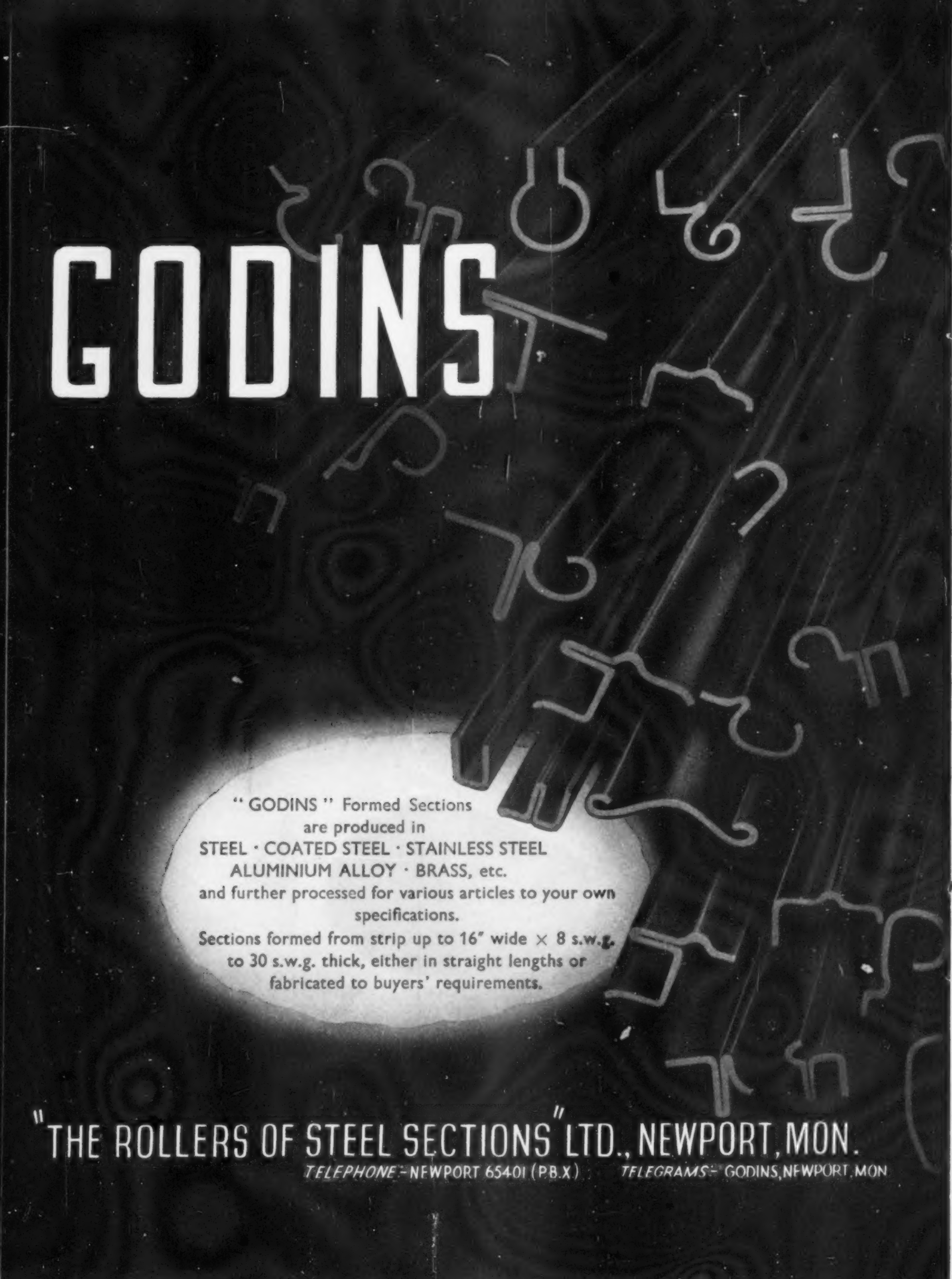
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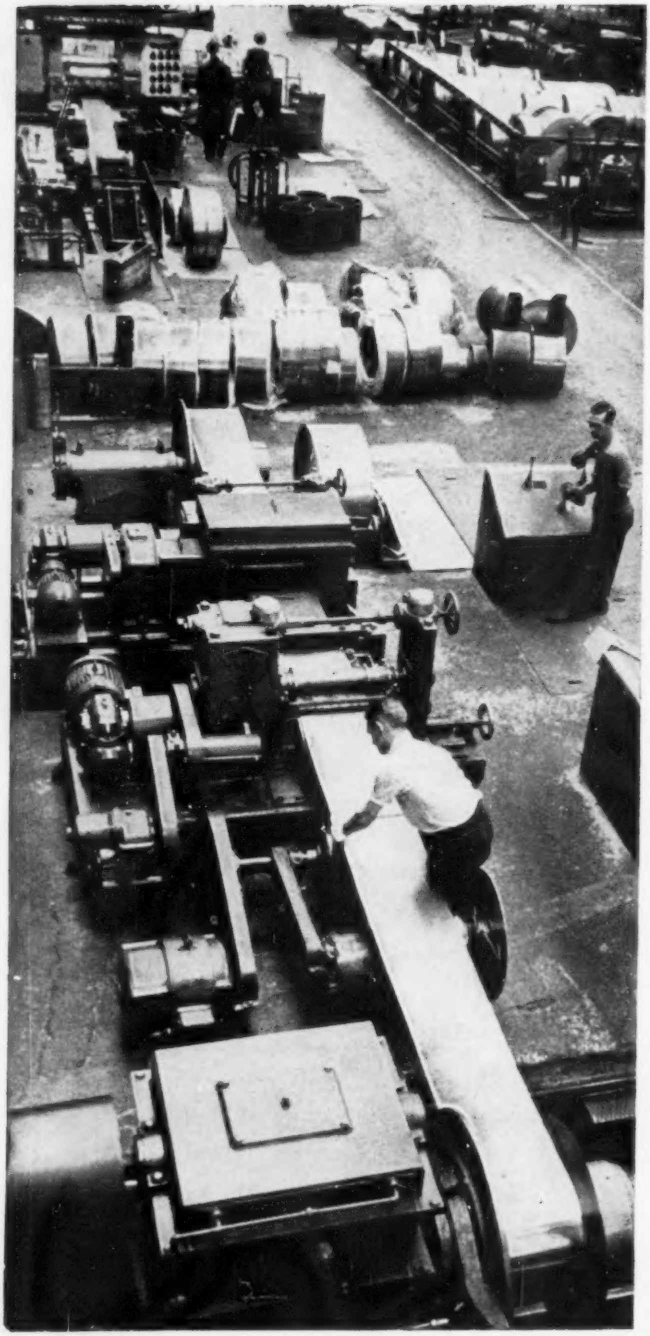

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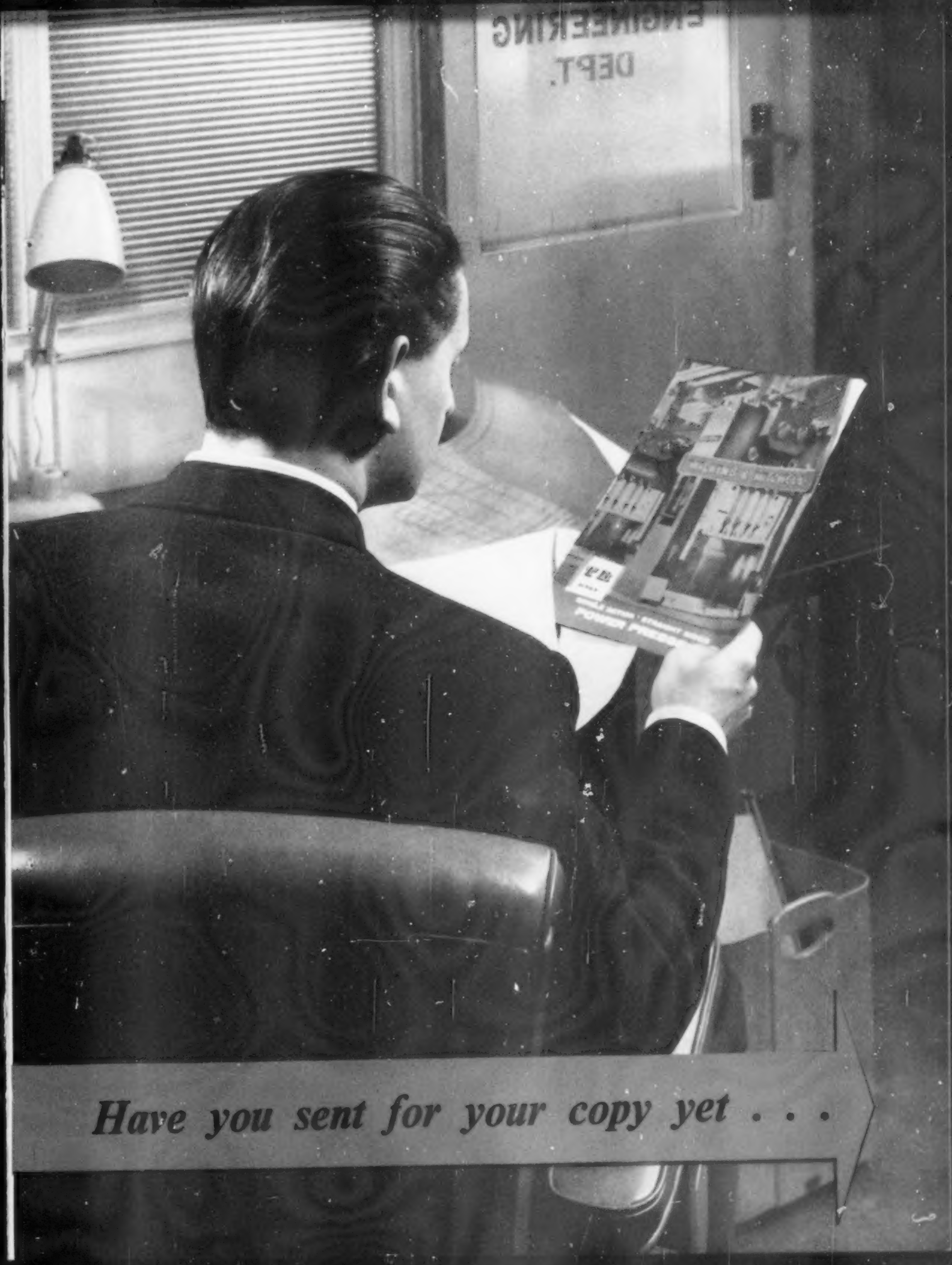
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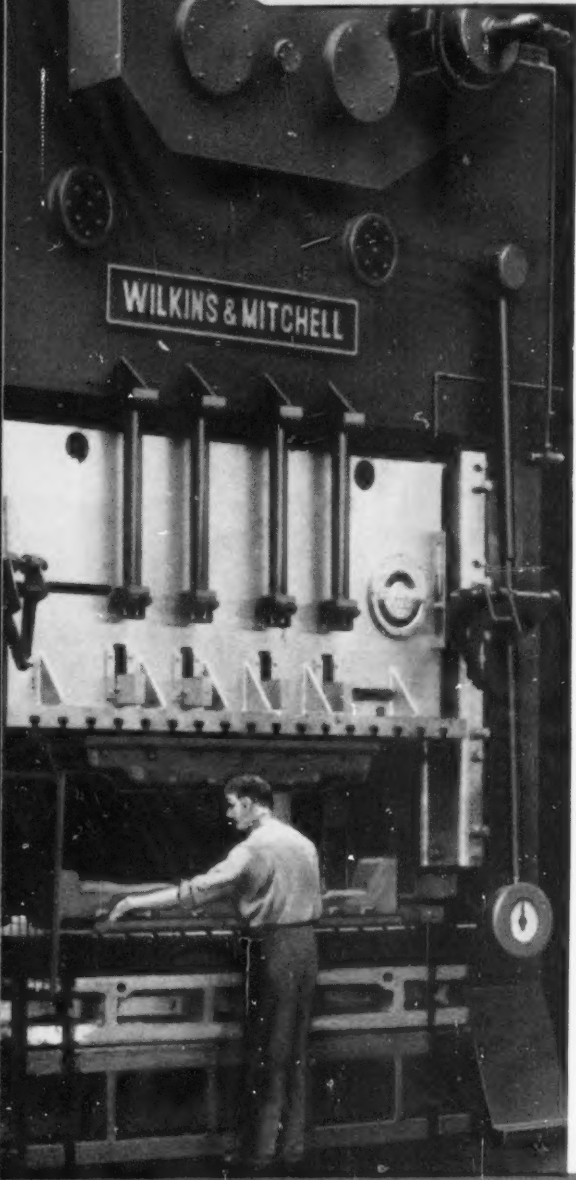

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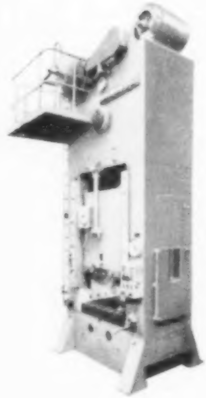

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- **DEEP-BEAM ALL STEEL SLIDE**
- **ALL-STEEL HEAVY SECTION FABRICATED CONSTRUCTION**
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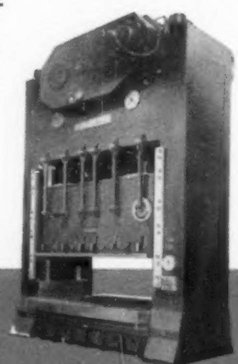

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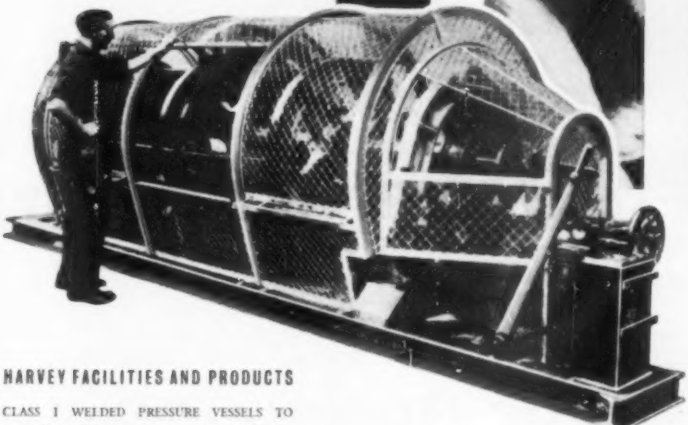

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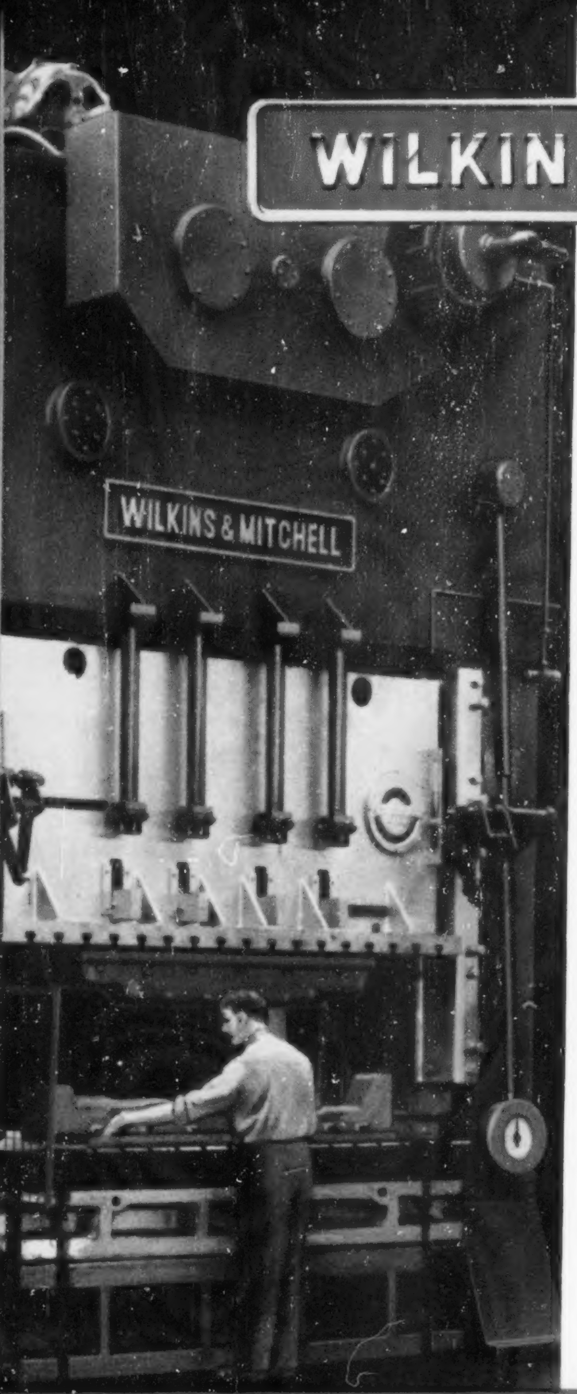

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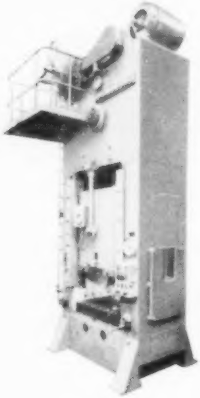
STRAIGHT-SIDED SINGLE-ACTION T.R. SERIES POWER PRESSES 1, 2 and 4 POINT SUSPENSION



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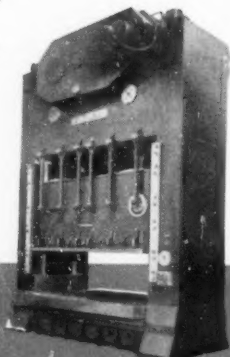

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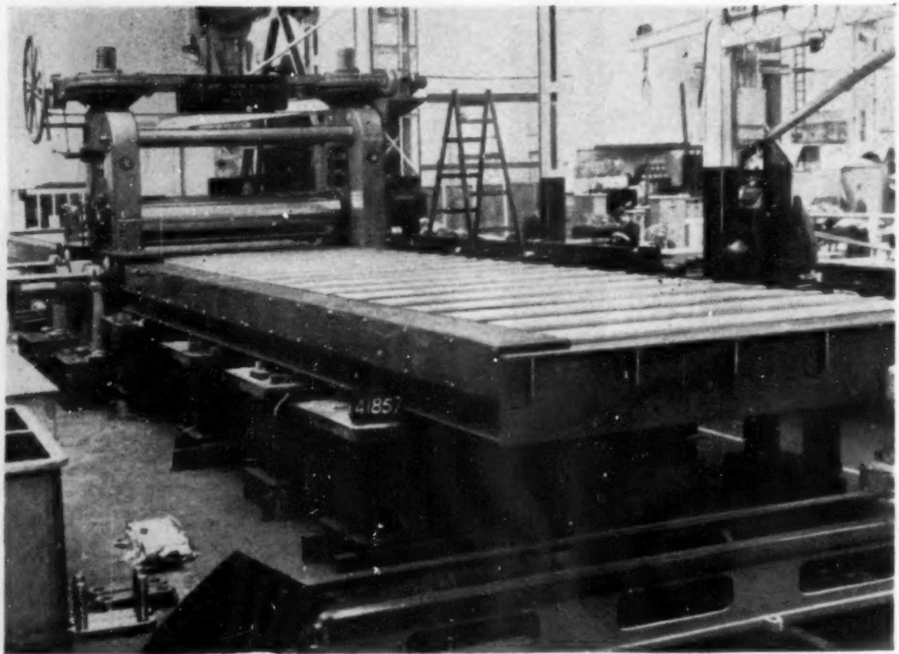

Lead Sheet Mill for 8 ft. wide Sheets.
Photograph by courtesy of Henry Halmshaw Ltd.

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A useful degree of red hardness at elevated temperatures has led to CCW being used also for hot heading dies, forming and piercing tools and purposes where short contact with hot metal involves only restricted rise in tool temperature. Very clear printed data on this steel is available upon request.

Heavy punches
Press and forming tools
Dies and rings for metal containers
Casement tools for mild steel
Caulking and bending tools
Cold heading die
Hot heading
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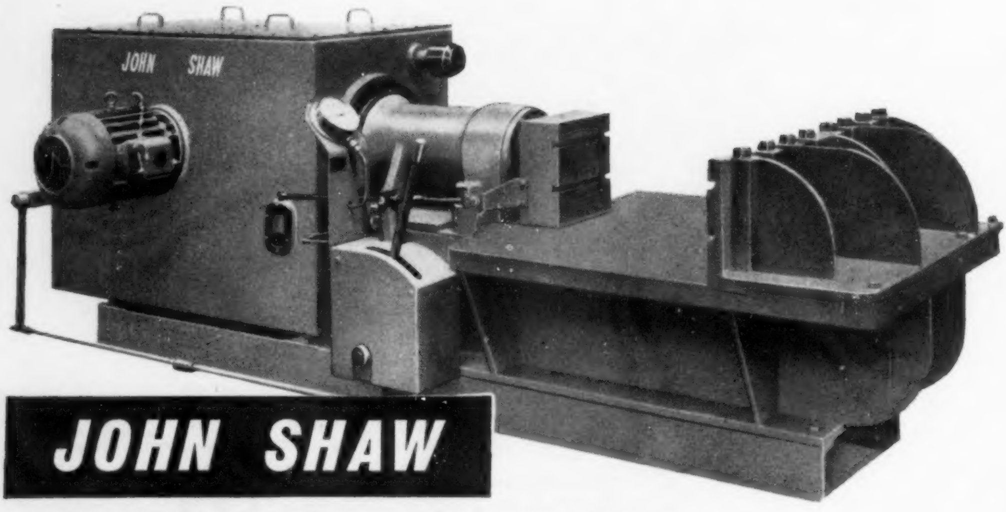

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Width of bed, 3′10″; working height from floor 2′1″; pressing block 13″ high; maximum working distance between crosshead and block 2′5″; travel of crosshead 15″.

Operating Speeds:-

Quick approach	70″ per min.
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Pressing speed from 25 tons to 50 tons	9″ per min.
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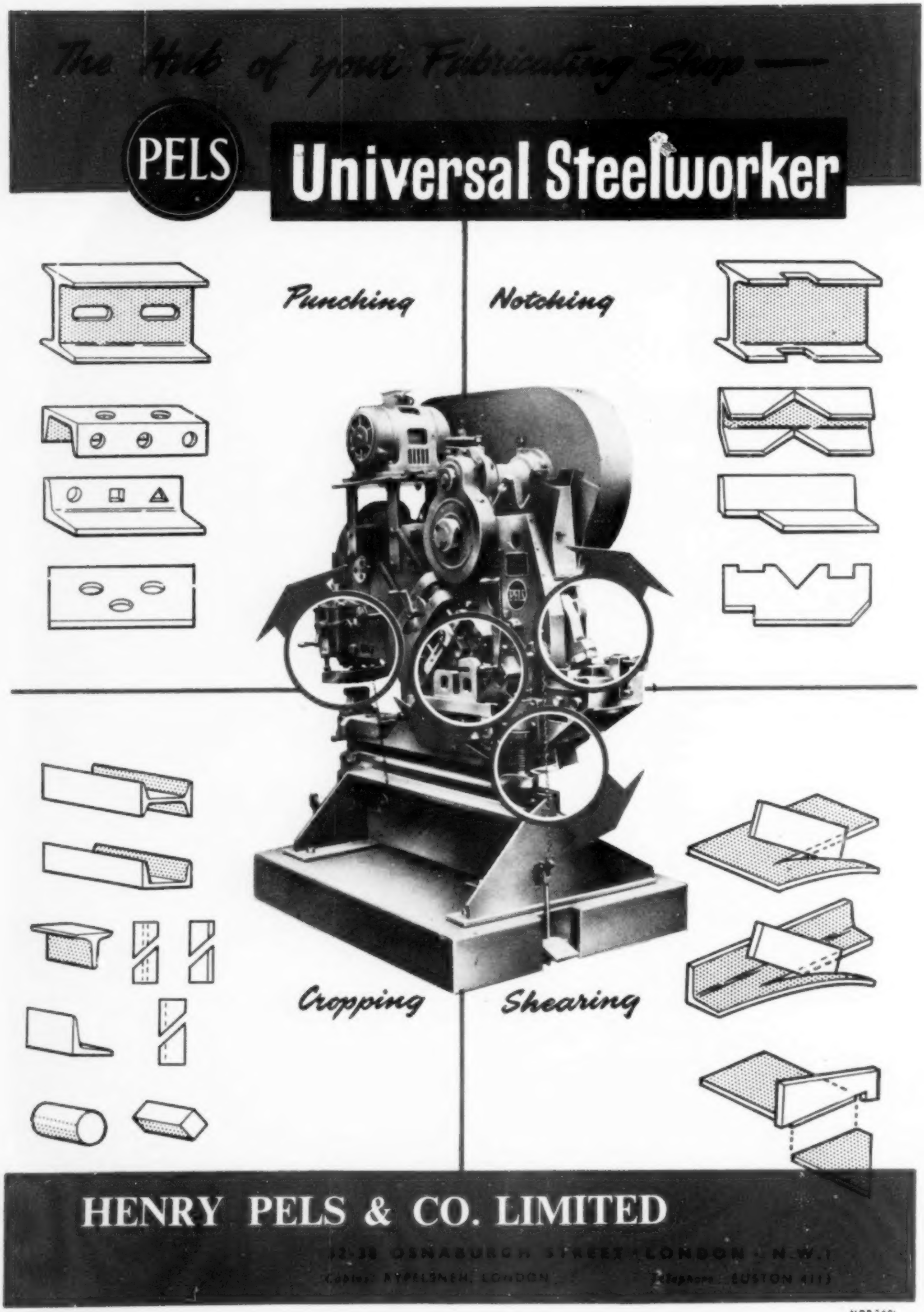

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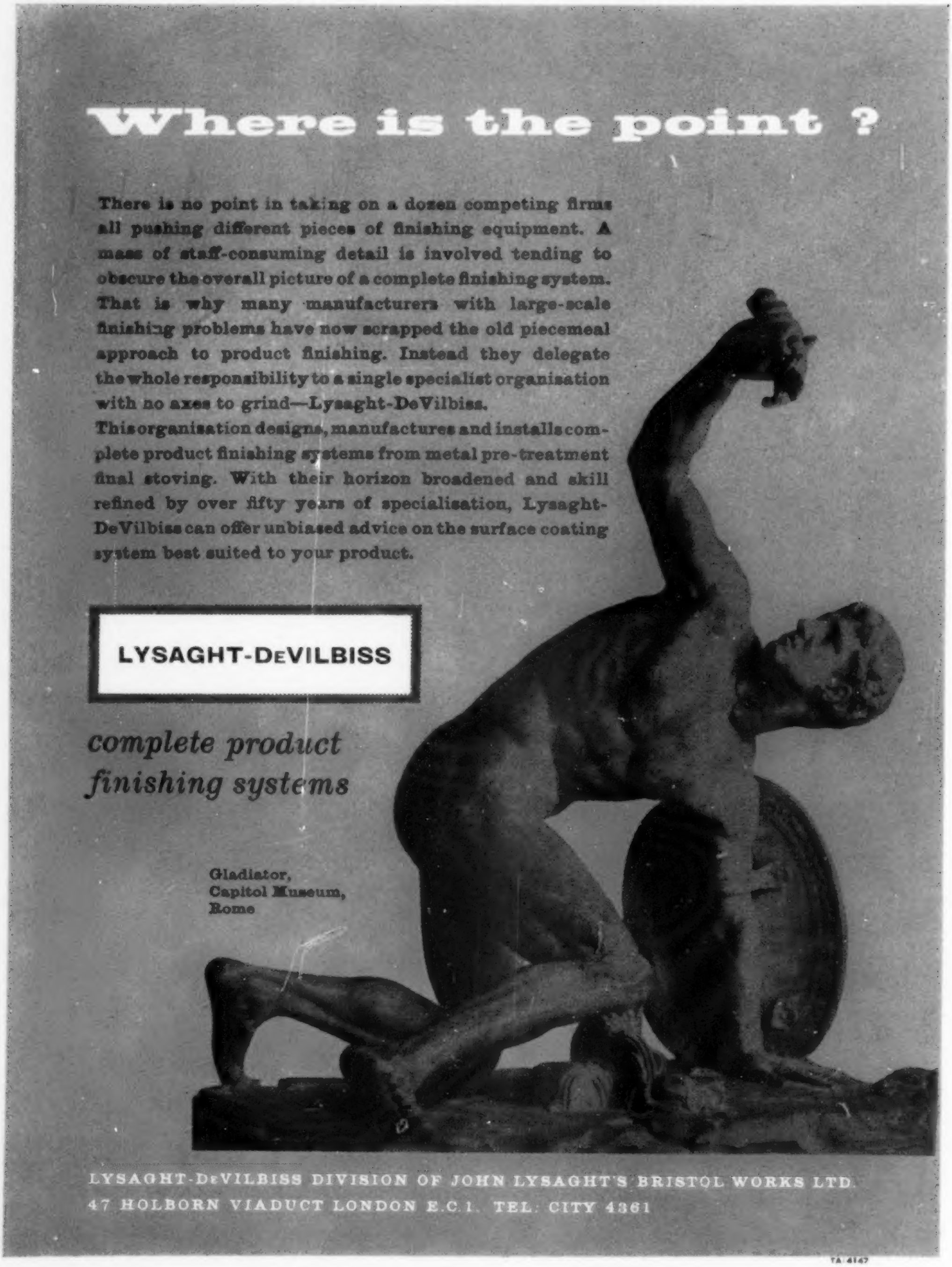
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Originally they were known simply as "The Wednesday" —this title being adopted from the mid-week day off on which matches were played.
In 1929 the name of Sheffield was added, and the city of Sheffield, the heart of the nation's Steel Industry, has since been proud of the link forged, for this Club has shown the strength and resilience of the steel that has also helped to make Sheffield famous.
Sheffield Wednesday's fluctuations between the Second and First Divisions in recent years have often had the Club dubbed the "yo-yo team". They have, in fact, been relegated three times since the end of the war, but four times they have battled their way back into the top grade.
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Sheffield Wednesday

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SAVE CAPITAL AND PRODUCTION SPACE BY ORDERING STEEL CUT TO YOUR SPECIFIC REQUIREMENTS, AS AND WHEN YOU NEED IT.
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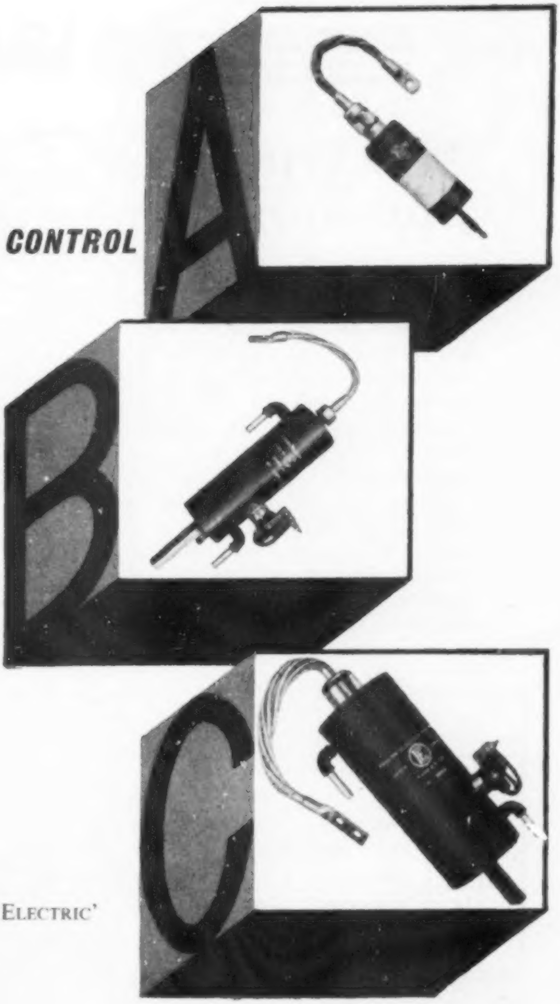

Accuracy and reliability of welding control are ensured by installing 'ENGLISH ELECTRIC' ignitrons, available from stock in the international sizes A, B and C.
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RIG.6A

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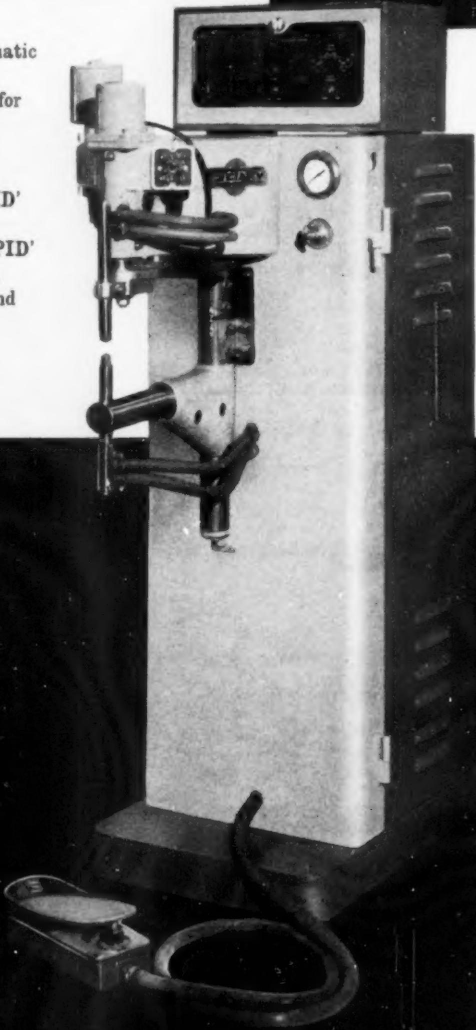

KVA	WELDING CAPACITIES		
	THROAT DEPTH	M.S. SHEET	M.S. WIRE
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	18"	.072"+.072"	.250"+.250" dia.
25	18"	.160"+.160"	.400"+.400" dia.
	24"	.125"+.125"	.375"+.375" dia.
	30"	.104"+.104"	.375"+.375" dia.
50	18"	.250"+.250"	.625"+.625" dia.
	24"	.187"+.187"	.500"+.500" dia.
	36"	.144"+.144"	.400"+.400" dia.

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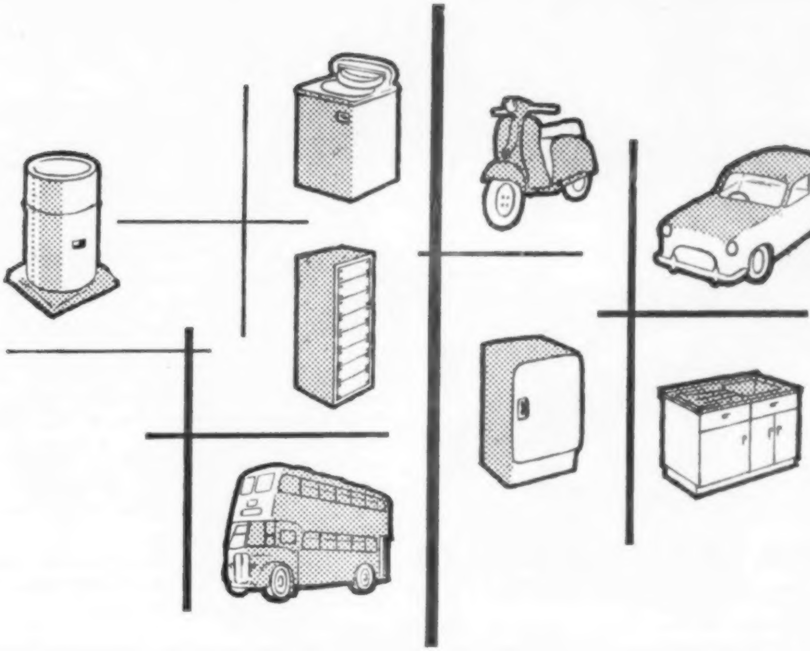

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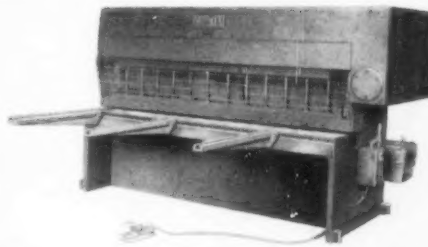
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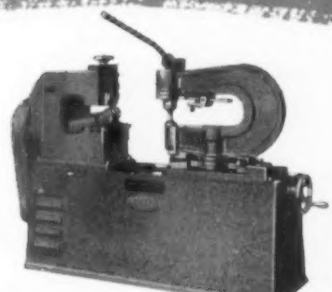
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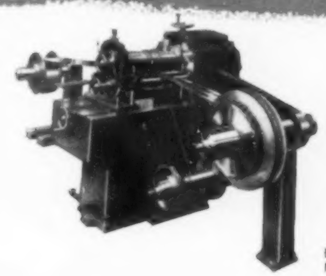
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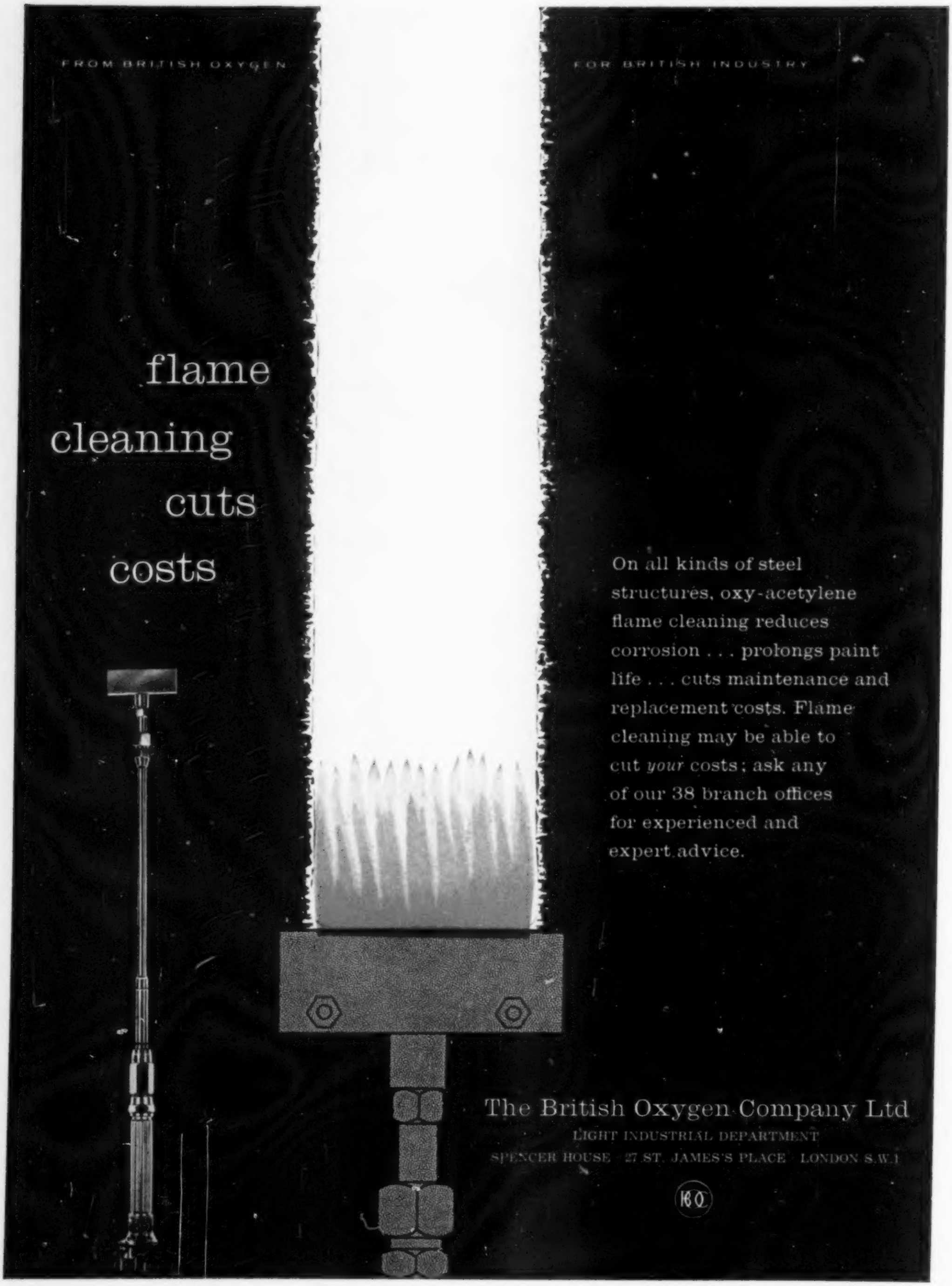
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FOR BRITISH INDUSTRY
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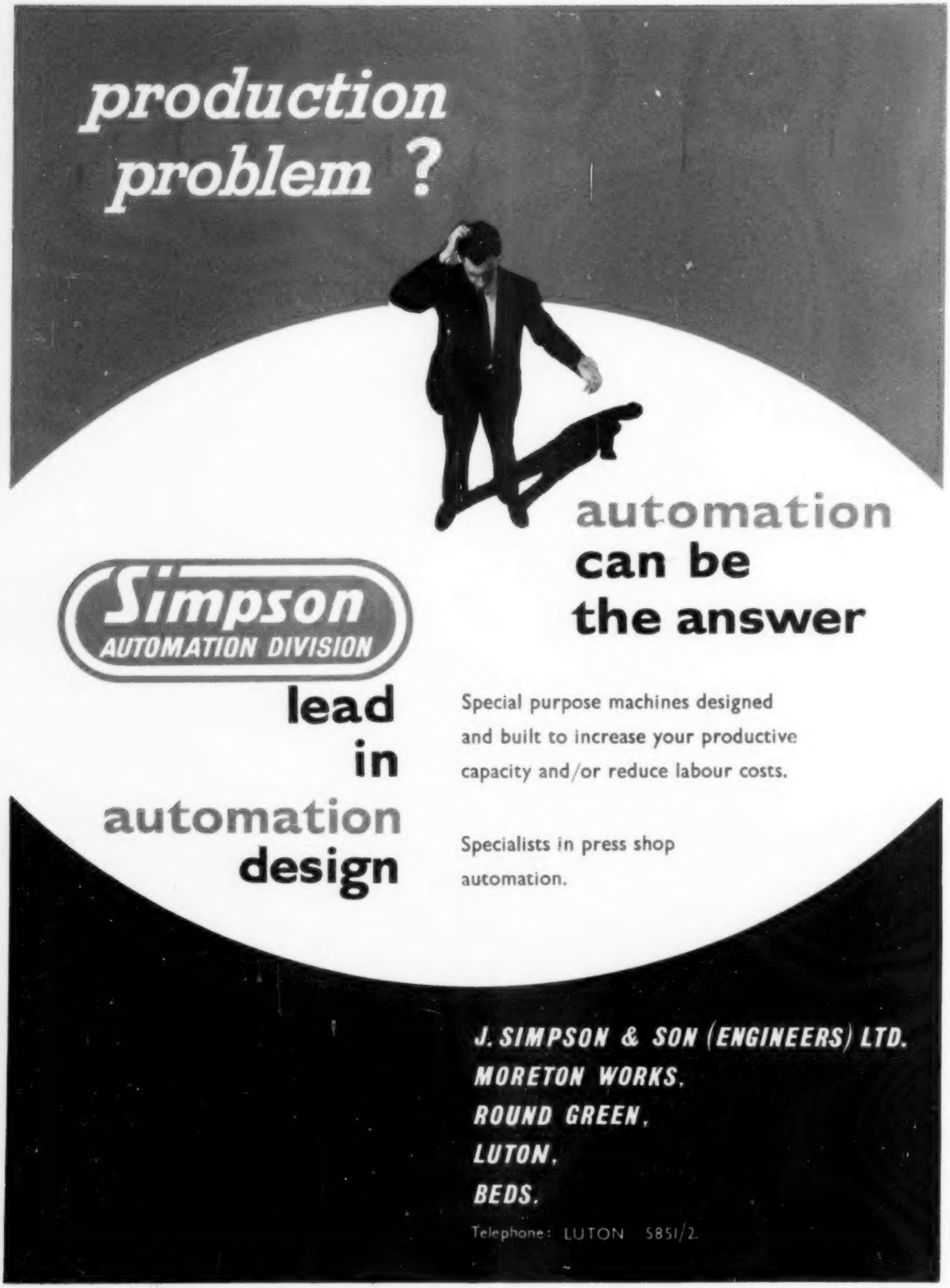
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automation can be the answer
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AUTOMATION DIVISION
lead in automation design
Special purpose machines designed and built to increase your productive capacity and/or reduce labour costs.
Specialists in press shop automation.
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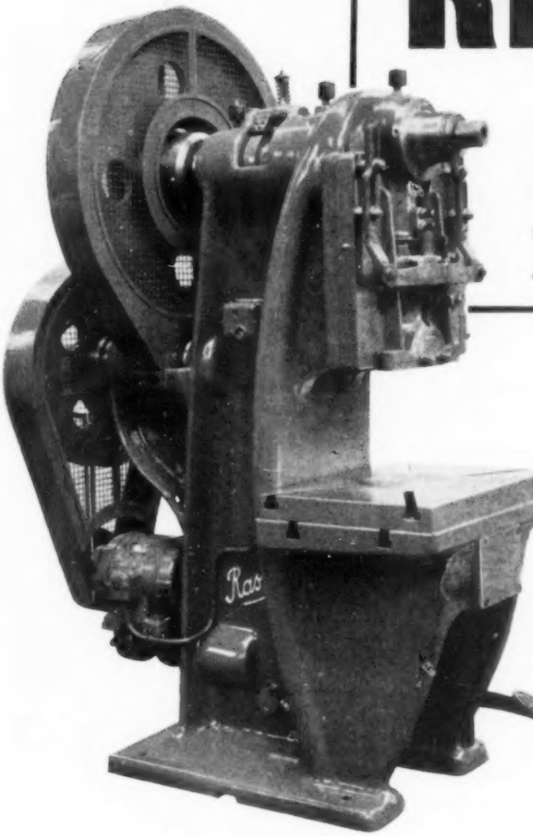
FOR MAXIMUM TOOL LIFE AND MINIMUM MAINTENANCE



Model	*Capacity in tons*	*Adj. of stroke*	*Bed Area*
R.2 Ungeared	20	3/8"–2 3/8"	17 3/4" × 13 3/4"
R.3 ,,	30	3/8"–2 3/8"	19 3/4" × 15 3/4"
R.4 ,,	50	3/8"–3 1/8"	25 1/2" × 19 3/4"
R.5 ,,	80	3/8"–3 15/16"	25 1/2" × 20 1/2"
R.6 ,,	100	3/4"–3 15/16"	29 1/2" × 23 1/4"
R.3A Geared	30	3/8"–3 1/8"	19 3/4" × 15 3/4"
R.4A ,,	50	3/4"–4 3/4"	25 1/2" × 19 3/4"
R.5A ,,	80	3/8"–3 15/16"	25 1/2" × 20 1/2"
R.6A ,,	100	3/4"–3 15/16"	29 1/2" × 23 1/4"
R.7 ,,	120	3/4"–4 3/4"	35 1/2" × 24 3/4"
R.7A ,,	150	3/4"–5 1/2"	42 1/4" × 27 1/2"
R.8 ,,	200	1 9/16"–7 3/32"	46 1/4" × 29 1/2"
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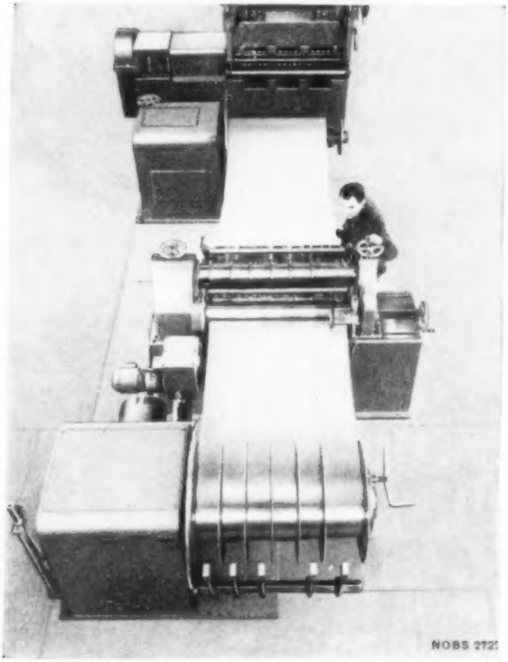

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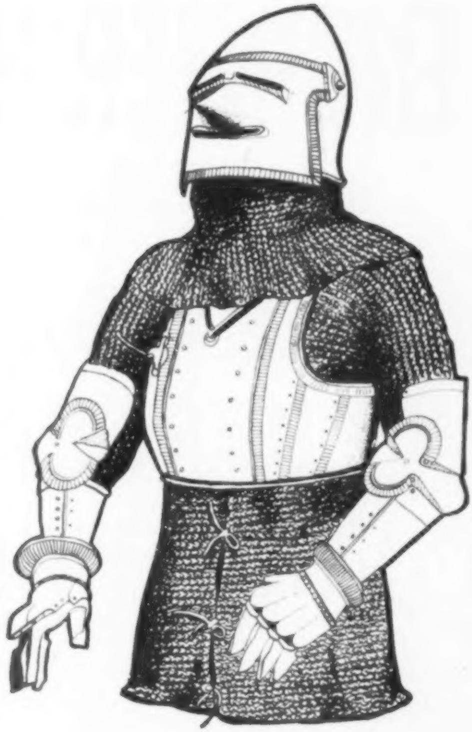

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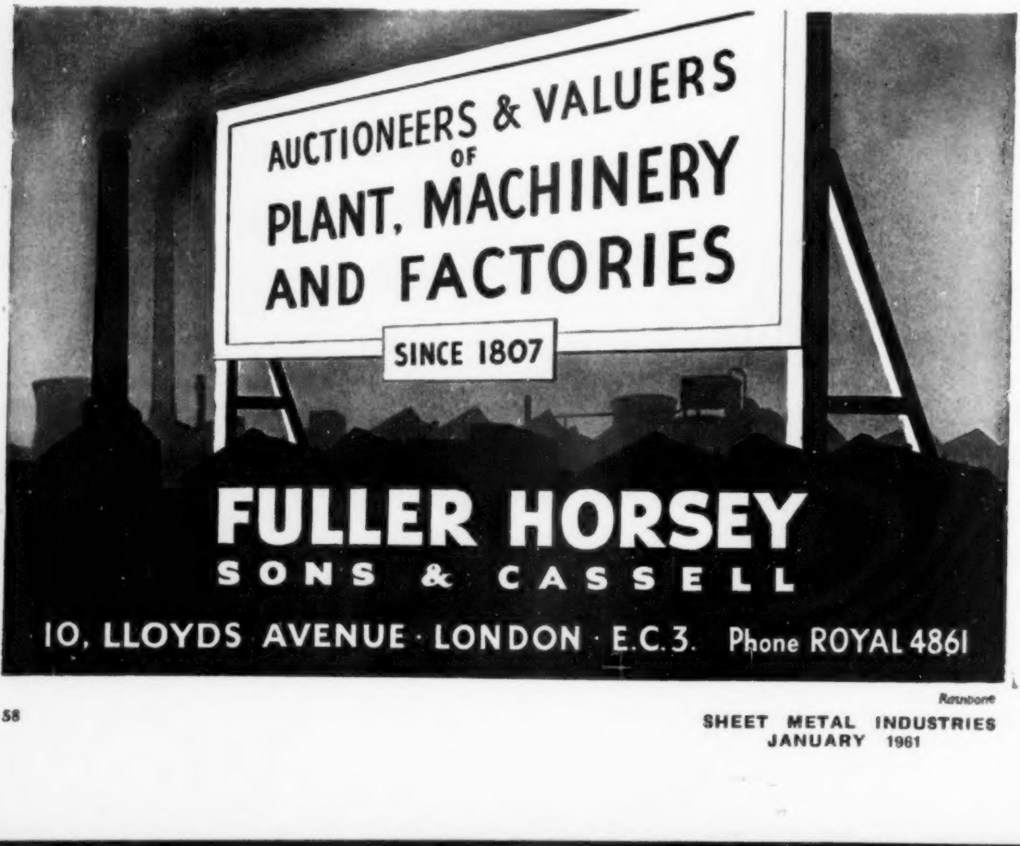

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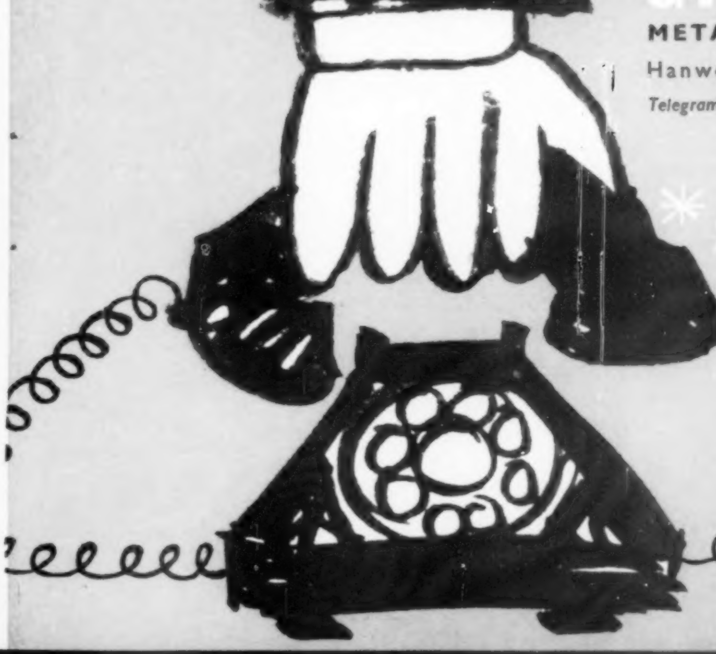

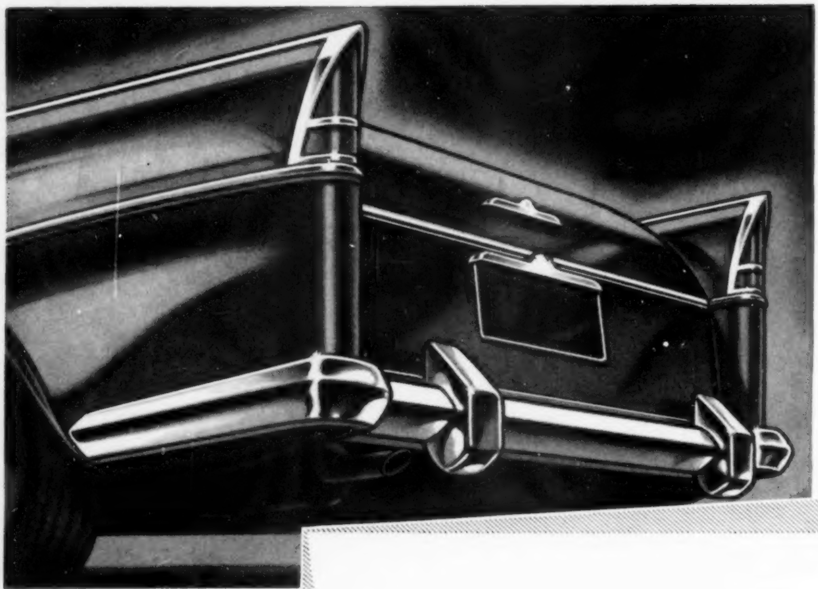

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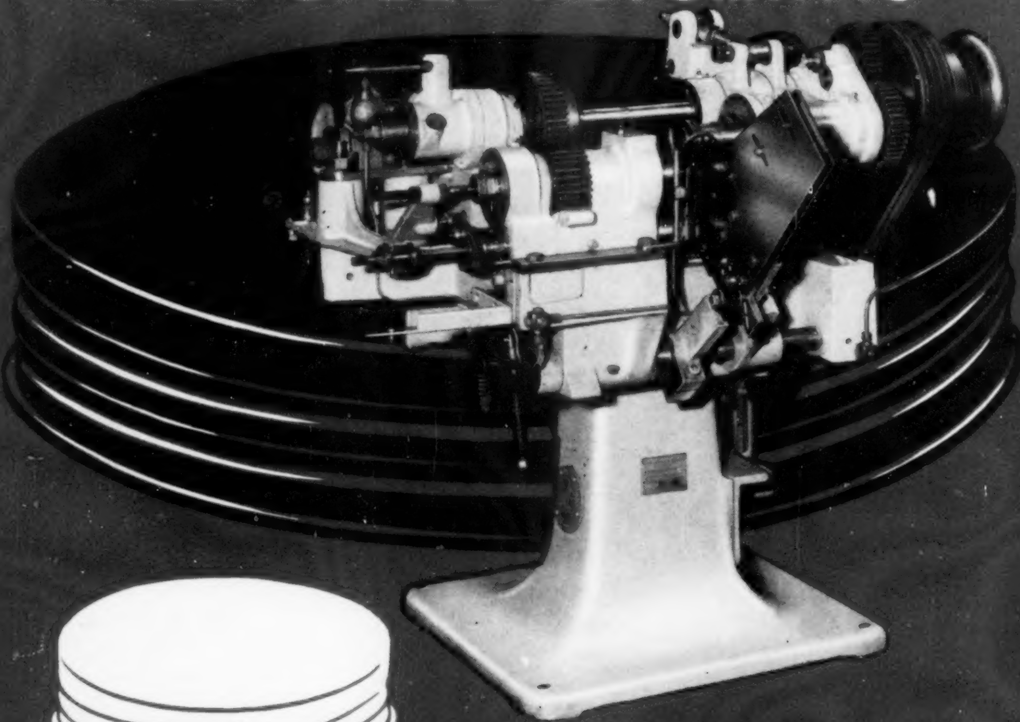

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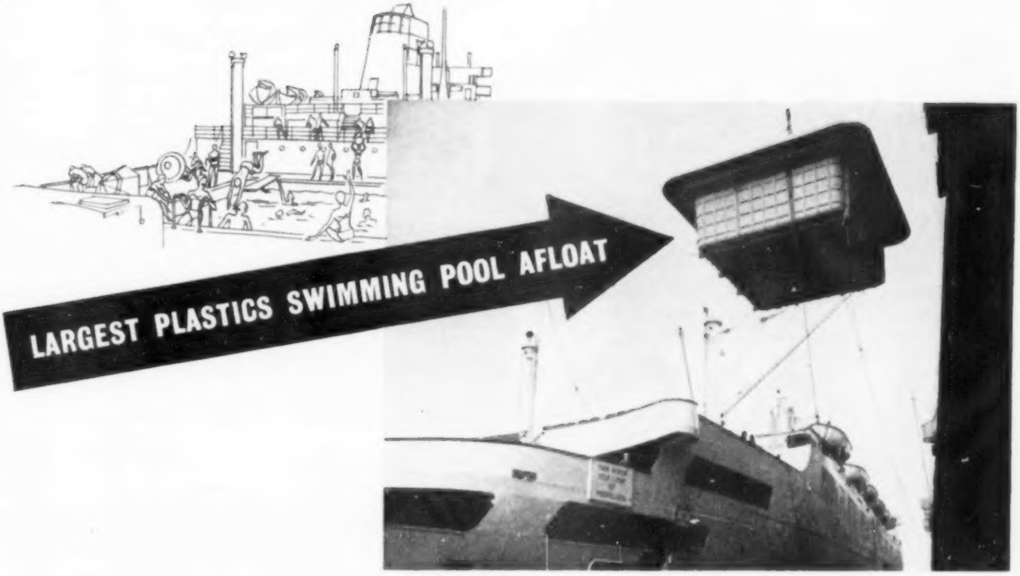

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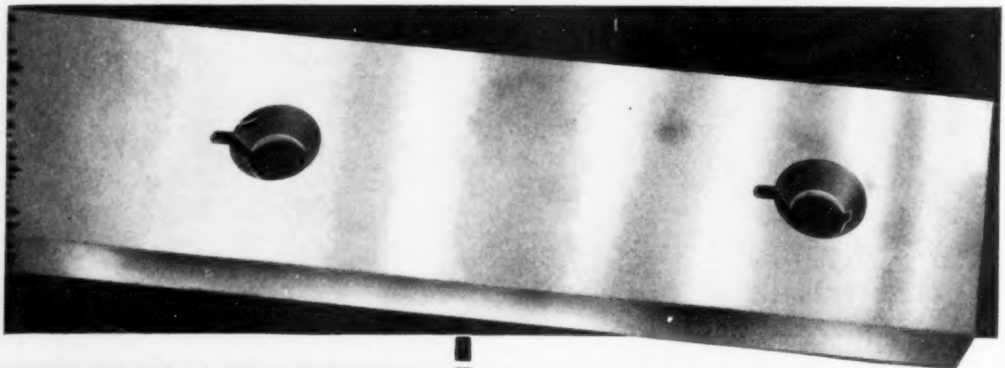

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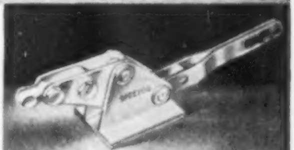

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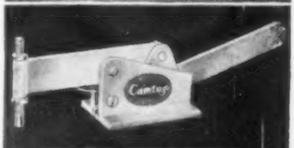

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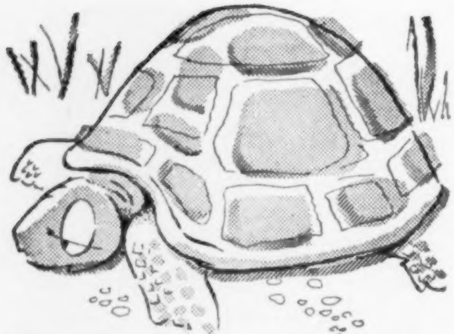

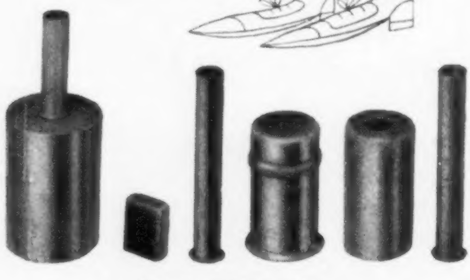

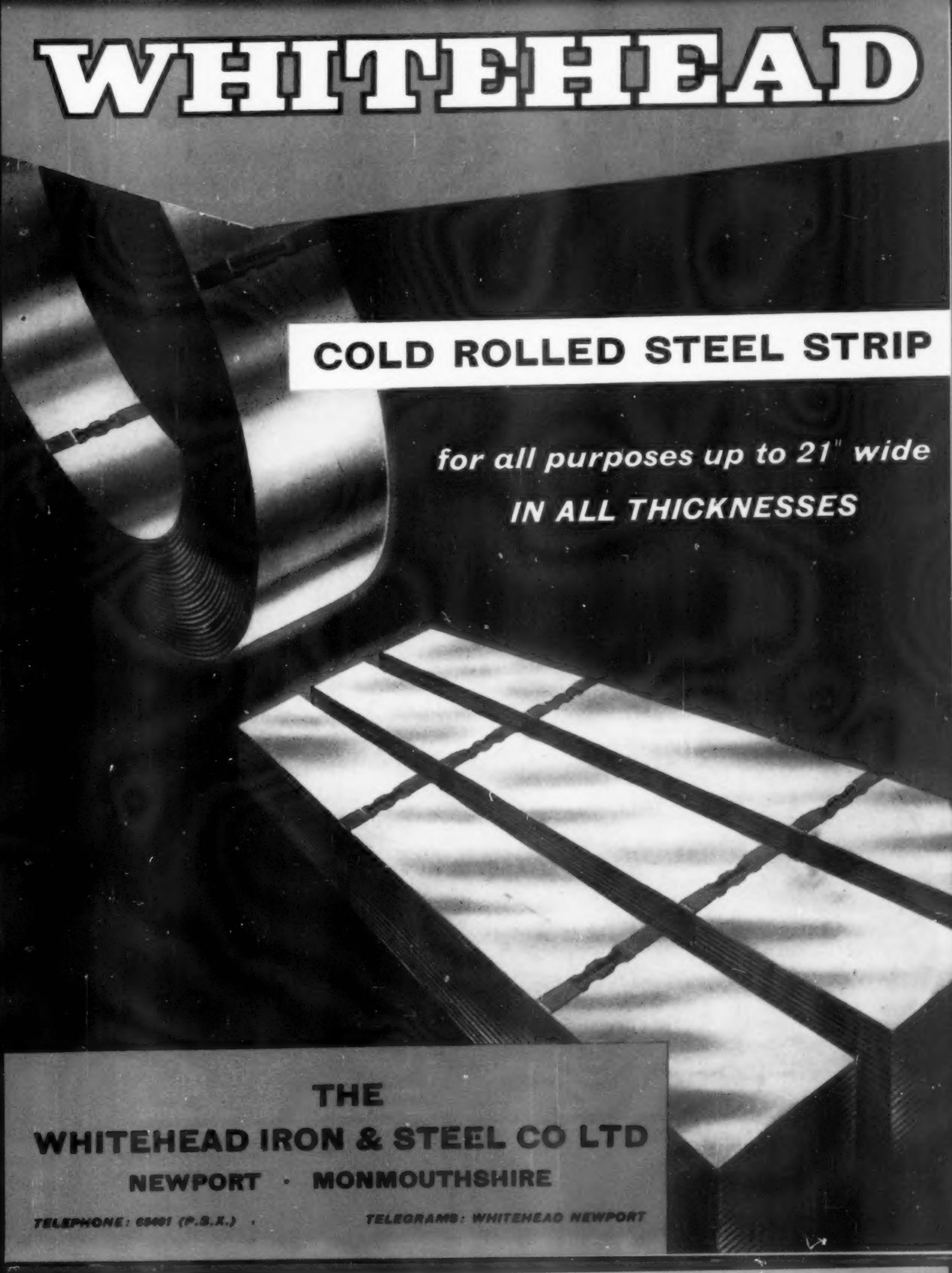
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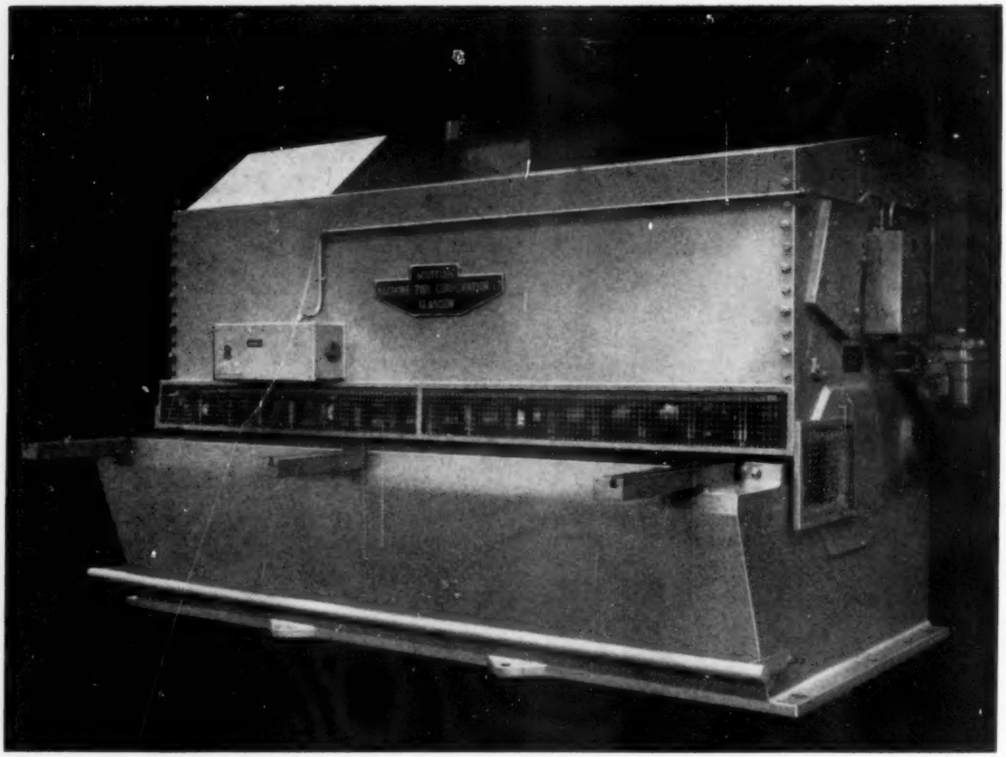

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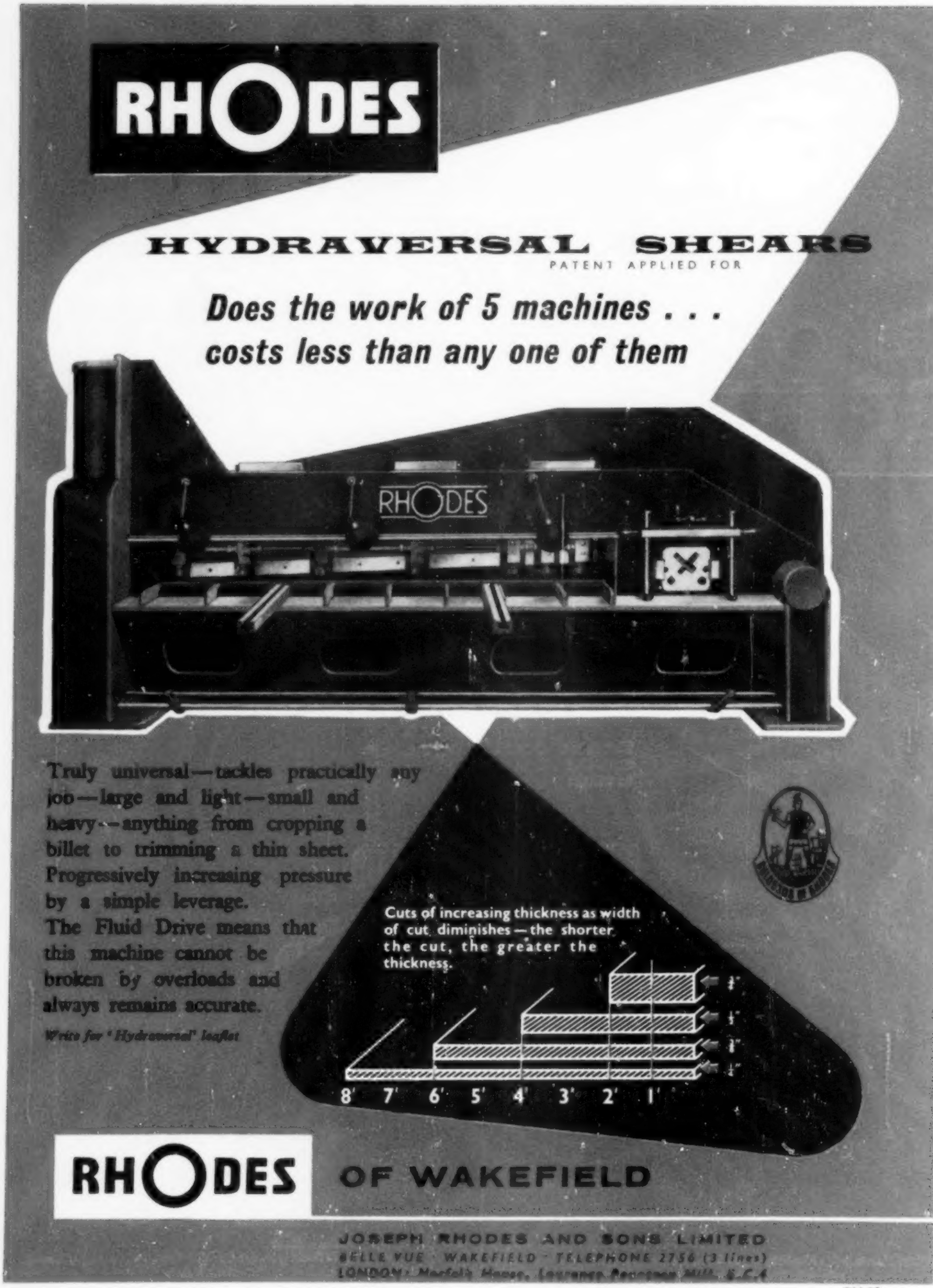

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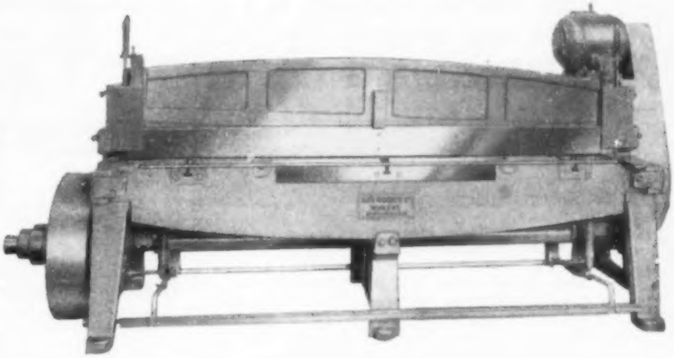

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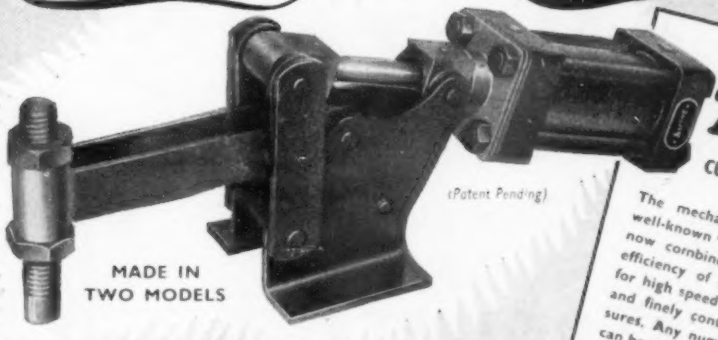

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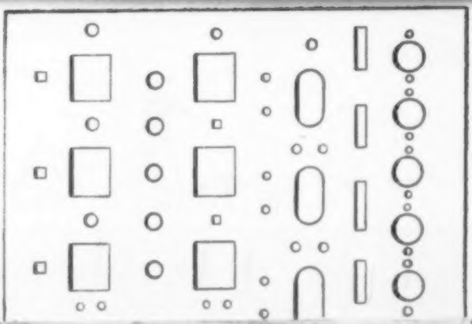

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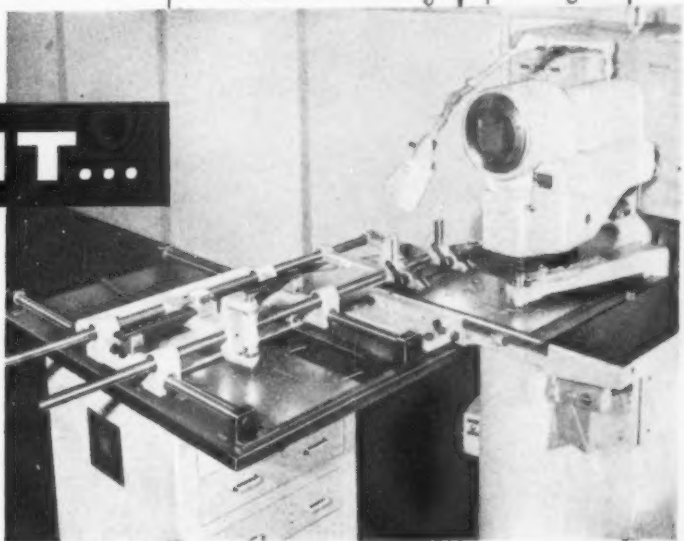

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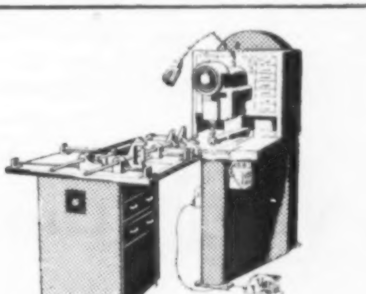

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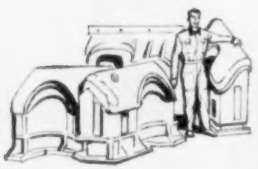

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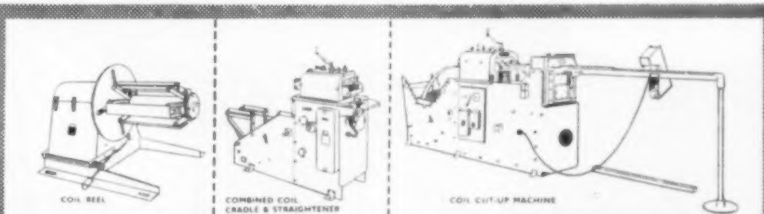

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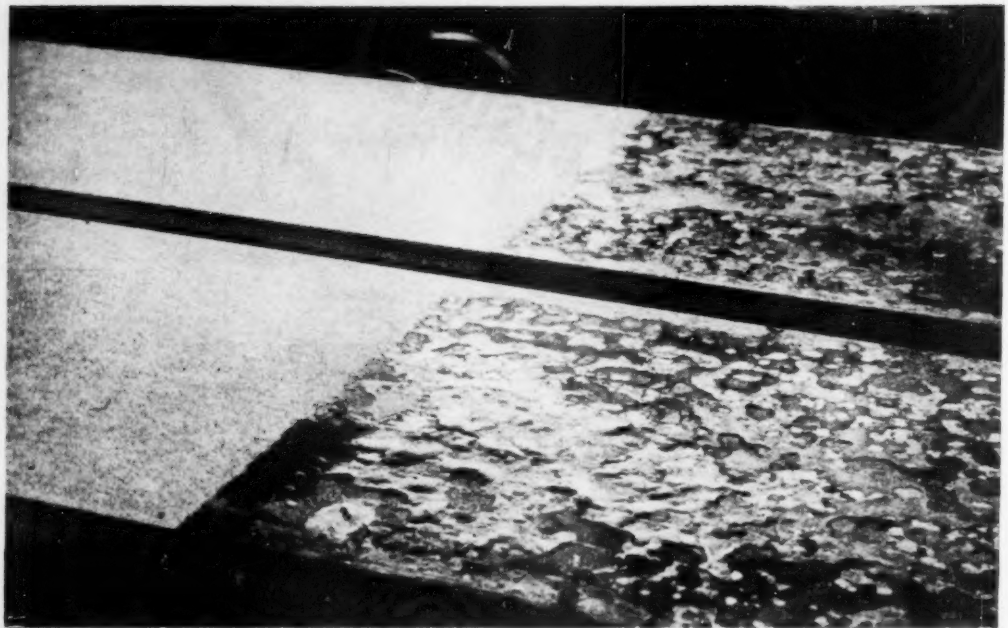

JANUARY 1961
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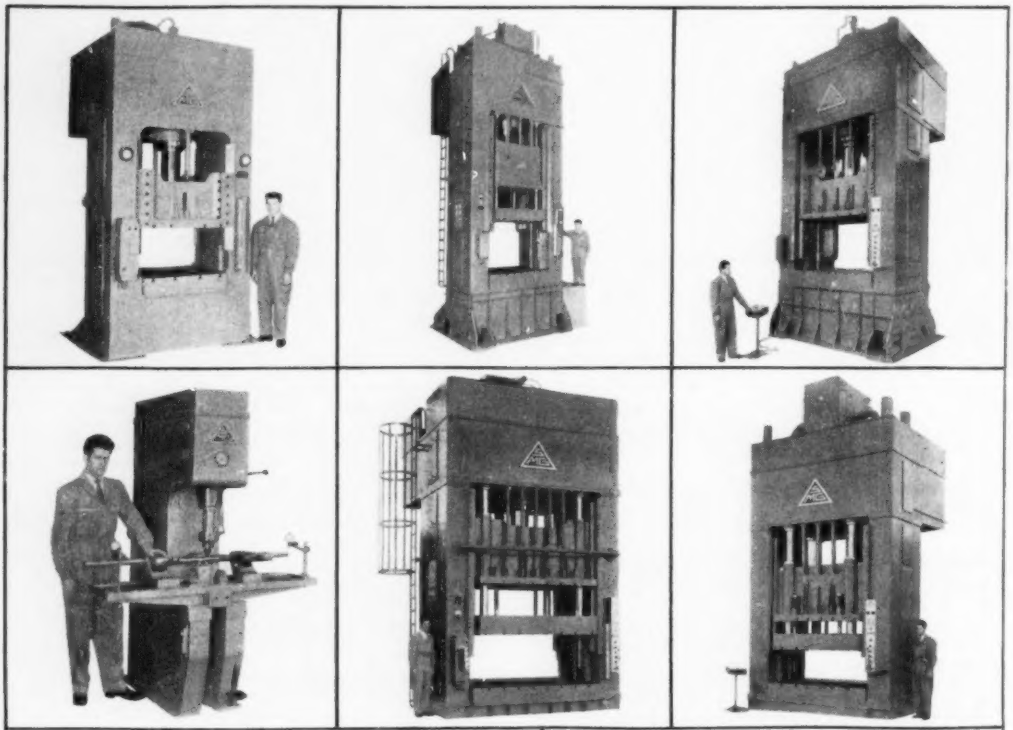

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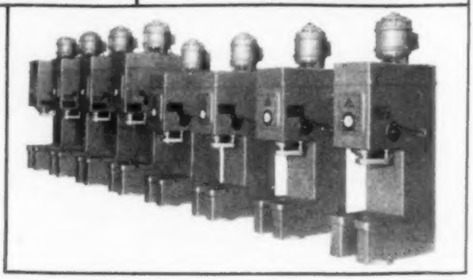

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Renseignements Pratiques sur la Production Industrielle et L'Emploi de Pièces Refoulées à Froid .. .. page 14

R. E. Okell, B.Sc., A.I.M., A.C.T. (Birm.)

Ces deux mémoires sont parmi les onze qui ont été présentés à une conférence spéciale au sujet du refoulage à froid des métaux, qui s'est tenue récemment à Sheffield, sous les auspices de l'Institute of Sheet Metal Engineering (Institut des Ingénieurs-Tôliers). Le Dr. Feldmann examine le procédé du point de vue de la production quantitative économique, et décrit une suite caractéristique d'opérations dans la fabrication de différents genres de pièces, et en particulier, du système "Colforg," pour lequel il établit les prix d'achat de l'équipement. Mr. Okell traite du choix des pièces et de leur conception, de la préparation des phases de l'emboutissage et de l'outillage nécessaire, du choix des aciers convenables au refoulage à froid, des traitements préparatifs et de l'emploi des pièces refoulées à froid. Enfin, nous donnons le compte rendu des débats qui ont suivi la présentation de ces mémoires.

Expérience de Formage par Etirage à Réaliser sur une Presse à Etirer à Vitesses Variables page 25

D. V. Wilson, B. B. Moreton et R. D. Butler

Les auteurs suggèrent que, tant que les expériences de formage par étirage peuvent jouer un rôle important dans les essais simulateurs destinés à prévoir le comportement des matériaux au cours du formage des tôles, il serait utile de poursuivre les études afin de satisfaire à ce besoin. Ils décrivent une expérience qui a été développée à l'Université de Birmingham et qui peut être réalisée sur une presse à étirer "Swift." Il est fait usage pour cette expérience, d'un poinçon de 2 inch (soit 50 mm) de diamètre, à tête hémisphérique, qui permet un choix de vitesses de pénétration allant jusqu'à environ 100 pieds (env. 305m) à la minute. Ils présentent les résultats de cette expérience qui démontrent certains avantages découlant de l'emploi d'un grand outil et d'une vitesse d'emboutissage variable. Ils décrivent une méthode de vérification rapide qui élimine la nécessité d'arrêter le poinçon au moment précis de la rupture.

Métallisation .. .. page 37

Au cours de la récente assemblée annuelle de l'International Institute of Welding (Institut International de la Soudure) un colloque s'est tenu pour examiner la métallisation, sous l'égide de la Commission I de l'Institut. On y a présenté certains mémoires au sujet de la physique de la pulvérisation à la flamme; de la préparation pour la pulvérisation; des matériaux pulvérisés et des propriétés de la couche pulvérisée; de la pulvérisation d'oxyde d'aluminium à la flamme; de la pulvérisation à la flamme d'oxydes métalliques destinés, entre autres, à l'usage à hautes températures; de la pulvérisation des métaux pour la protection du fer et de l'acier; de la protection contre la corrosion à haute température; de la pulvérisation au zinc pour l'industrie hydroélectrique; de l'économie de la pulvérisation métallique; de spécifications pour la pulvérisation des métaux et des problèmes relatifs à l'enseignement de ce sujet. Cette revue générale des mémoires a été préparée par le Prof. G. A. Herpol, membre rapporteur de la Commission.

(Suite page 70)

ZUSAMMENFASSUNGEN DER HAUPTARTIKEL

Wirtschaftliche Verwendung von Kaltgeschmiedeten Teilen .. .. .. Seite 8

Dr.-Ing. H. D. Feldmann

Erfahrungen bei der industriellen Herstellung und der Verwendung von Kalt-Extrudierten Stahlteilen .. .. Seite 14

R. E. Okell, B.Sc., A.I.M., A.C.T. (Birm.)

Die beiden genannten Vorträge wurden im Rahmen einer Reihe von insgesamt 11 Vorträgen auf der kürzlich vom Institute of Sheet Metal Engineering in Sheffield abgehaltenen Sonderkonferenz gehalten, die das Kalt-Strangpressen von Stahl zum Gegenstand hatte. Dr. Feldmann behandelt das Verfahren unter dem Gesichtspunkt der wirtschaftlichen Produktionsmenge und beschreibt typische Arbeitsvorgänge bei der Herstellung verschiedener Arten von Teilen unter besonderer Berücksichtigung des "Colforg"-Verfahrens, für das er Anlagekosten angibt. Mr. Okell befaßt sich mit Auswahl und Entwurf des Preßteils, Konstruktion der verschiedenen Presstufen und Werkzeuge, Stahlauswahl für das Kalt-Extrudieren, Vorbehandlung sowie der Verwendung kalt-extrudierter Teile. Die den Vorträgen folgende Diskussion ist eingeschlossen.

Eine Streckformprüfung zur Anwendung an einer Ziehpresse mit Regelbarer Geschwindigkeit .. .. Seite 25

D. V. Wilson, B. B. Moreton und R. D. Butler

Während den Streckformprüfungen eine möglicherweise bedeutende Rolle als simulative Prüfung zur Vorausbestimmung des Materialverhaltens beim Blechverformen zugebilligt wird, halten die Verfasser hierzu gewisse Weiterentwicklungen für nötig. Es wird eine an der Universität Birmingham entwickelte Prüfung beschrieben, die an einer Swift Ziehpresse durchgeführt werden kann. Sie verwendet einen normalen Stempel mit halbkugelförmigen Kopf von 50 mm Durchmesser und gestattet Eindringgeschwindigkeiten bis etwa 0,5 m/s.

Angegebene experimentelle Ergebnisse veranschaulichen einige Vorteile des großen Werkzeugs und der regelbaren Ziehgeschwindigkeit. Ein Schnellprüfverfahren, bei dem der Stempel nicht genau im Augenblick des Bruches gestoppt zu werden braucht, wird beschrieben.

Metallspritzen .. .. .. Seite 37

Auf der kürzlich stattgefundenen Jahresversammlung des International Institute of Welding wurde unter der Ägide der ersten Kommission des Instituts ein Kolloquium über „Metallspritzen" abgehalten. Die Vorträge behandelten die Physik des Flammspritzens, Vorbereitung zum Spritzen, Spritzstoffe und Eigenschaften der Schicht, Flammspritzen von Aluminiumoxyd, Flammspritzen von Metalloxyden für Hochtemperatur- und andere Zwecke, Metallspritzen zum Schutz von Eisen und Stahl, Heißkorrosionsschutz, Zinkspritzen in der hydroelektrischen Industrie, die wirtschaftliche Seite des Metallspritzens, Vorschriften für das Metallspritzen sowie Ausbildungsprobleme. Dieser zusammenfassende Bericht über die einzelnen Vorträge wurde von Prof. G. A. Herpol, dem berichterstattenden Mitglied der Kommission, angefertigt.

Materialien für Presswerkzeuge .. Seite 43

A. G. Shaw

In diesem Artikel behandelt der Verfasser Werkzeugmaterialien eingeteilt nach Epoxyharzen, Zinklegierungen, Aluminiumbronzen und Werkzeugstählen. Die Entwick-

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A RESOLUTION

THE threshold of a new year is the traditional occasion for taking stock, examining one's past record and making resolutions for the future. While it is true that a study of history can provide some guidance as to the probable future trend of events, the major development which overshadows all our thinking and which is unique to our time is that now the human race, or some sections of it, have acquired the power to annihilate itself and possibly all other forms of life over the whole surface of the globe.

Such, however, is the organization of our society that the ultimate decision as to whether the race is to survive or not, is almost wholly without the power of the individual to influence, and one is left, in face of the ultimate issue, with power only to deplore those factors in the human make-up which render the prospect of total extinction even a remote possibility.

Even on a lesser plane it is abundantly apparent that many decisions are taken by those with economic or political power without a full appreciation of what the ultimate effect on the general industrial and economic welfare of the community will be. Britain has been blessed by providence with only two basic natural resources, a reasonably accessible supply of high quality coal and a high degree of scientific and technical talent among its natives. The judicious interaction of both these resources brought about the so-called industrial revolution and won for this nation a position of pre-eminence as a manufacturing and exporting country, a position which involved the conversion of raw materials, with which other countries were more abundantly provided, into more complex saleable commodities.

In times long past, people in other lands bought goods from Britain because there were few, if any, other sources for such goods. Later, as other sources developed and multiplied, British goods could still find a ready market on the basis of quality and price. To-day, neither one nor the other can be taken automatically for granted. And yet virtually every ton of iron and aluminium, copper and zinc, rubber and tin, oil and uranium, needed to feed our factories as well as most of the food to feed the workers in them, must be brought to these shores from overseas and paid for by exports.

Sheet metal and the articles into which it is manufactured are among the most outstanding commodities by which this nation can earn its living. It is the firm resolve of SHEET METAL INDUSTRIES, as the Journal which uniquely serves this vital field, to use its world-wide circulation to the fullest effect to promote the interests of this paramount industry.

A Happy and Prosperous New Year

The Editor, the Advertisement Director and the Staff extend to all readers, advertisers, contributors and other friends in the industry at home and overseas, sincere and cordial good wishes for their happiness and greater prosperity in the Year that lies ahead.

COLD EXTRUSION OF STEEL

New Developments Discussed by Over Three Hundred Delegates at Conference in Sheffield

Institute of Sheet Metal Engineering Plans Further Investigations into the Process

WHEN the Institute of Sheet Metal Engineering sponsored in London in 1953 the first Conference on the Cold Extrusion of Steel, the proceedings were formally inaugurated by the Parliamentary Secretary to the Ministry of Supply, who said at the time that the emergence of the process of cold extruding steel seemed to him to be one of the really important technical advances of the post-war years. He went on to say that although plant requirements might be expensive, he was sure that the process would lead to many economies and that British industry could not afford to be left behind in taking advantage of an important, new development.

In the seven years which have elapsed since that meeting progress in developing and applying cold extrusion techniques to the production of steel components can hardly be said to have lived up to the Ministerial hopes. A certain amount of research and development work into the process was carried out under the sponsorship of the Ministry of Supply, the greater part of this work being done at Royal Ordnance Factories, first at Radway Green and subsequently at Birtley, but industry, in this country at least, appeared unenthusiastic over its prospects.

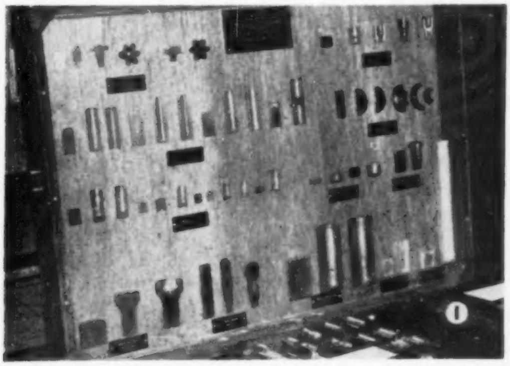
In an attempt to discover whether in fact any notable progress in applying the process has been made in recent years and to pinpoint such reasons as may exist for the lack of interest shown in the process by industry in general, the Institute of Sheet Metal Engineering staged a second Conference on the subject in the latter part of November last. This Conference was held in the Memorial Hall of the City Hall, Sheffield, and was attended by some 320 delegates over the two and a half day period of its duration. The number of papers presented was 11, which was four more than the number presented at the 1953 meeting, and several of the papers were supported by exhibits of extruded components or by films showing the extrusion process in action. The text of the two papers presented at the first technical session of this Conference appears in the following pages, together with a report of the discussion which followed their presentation. The papers and discussions at the remaining sessions will be published in subsequent issues of this Journal and it is expected that all the papers and discussions will be made available in due course as a single volume published by the Institute.

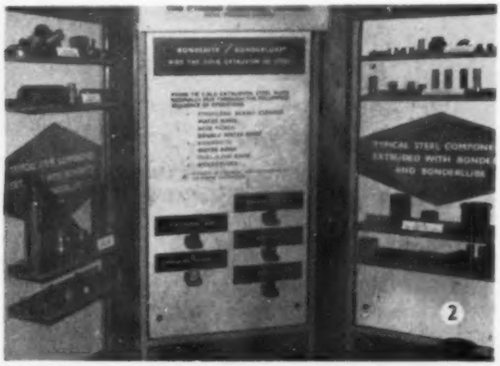
It was manifest from the tenor of the papers and the discussion that some work on cold extrusion has been carried out in this country in the past four or five years, but it is at the moment neither substantial nor widespread. One reason for this was suggested by one of the speakers at the Conference who commented in the course of his paper that the 1953 Conference as a whole was much too technical and the public findings were of such a nature that industry in Great Britain seemed completely unable to absorb any of the results of the proceedings into practical action. While this explanation may in some measure be a correct one it would appear to reveal a somewhat disconcerting state of affairs if it is in fact true that the exposition of the attributes of the process which was made at the 1953 meeting was of too complex an engineering nature for its findings to be of any use to those engineers responsible for development of production processes. It is more likely that the true explanation can be found in the notorious conservatism of the British engineering industries and in the large amount of very efficient metal removing

One of the lecturers at the I.S.M.E. conference was Mr. R. A. P. Morgan (Royal Ordnance Factory, Birtley). On his right is Dr. J. G. Wistreich, chairman of the session and Mr. Frank Griffiths (British Motor Corporation) who also presented a paper at this particular session

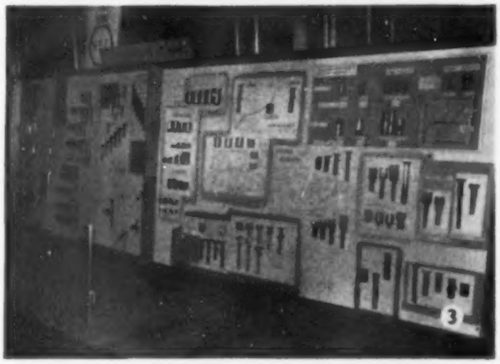
equipment to be found in the machine shops of this country.

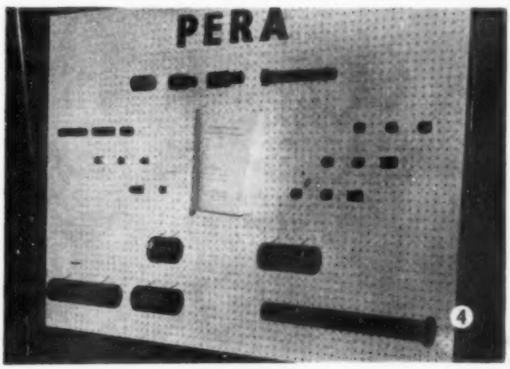
One of the many interesting facts which emerged from the present Conference was that the process, which has been consistently referred to here as Cold Extrusion, is regarded by some experts as being more closely related to forging practice and that as a process its most likely future appears to be as a successor to hot forging rather than as a supplement to deep drawing. It was with this latter possibility in mind that the technique was brought into the technical purview of the Institute of Sheet Metal Engineering as such evidence as existed in 1950 appeared to point to the process being used as a means of producing hollow shapes which would then be subjected to further deep drawing and pressing operations. While no clear pattern of trends can be said to have yet emerged in the application of the process, there does now appear to be reason to believe that it will attract substantially (*Continued in page* 70. *Conference papers and discussion begin on page* 8.)

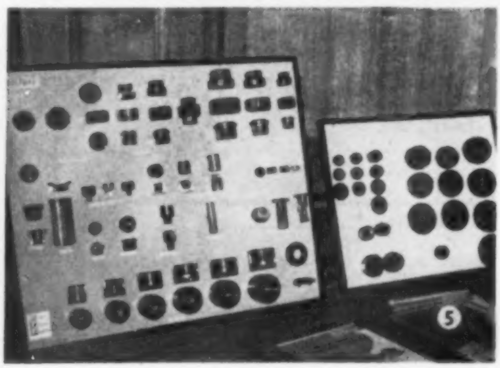




Some of the examples of cold extrusion shown in conjunction with the conference: (1) *Verson Allsteel Press Co.*, (2) *The Pyrene Co. Ltd. who showed cold extruded components from several companies including Forgings and Presswork Ltd.*, (3) *National Engineering Laboratory*, (4) *Production Engineering Research Association*, (5) *Cold Forging Ltd.*







Economical Use of COLD-FORGED COMPONENTS

By Dr. Ing. H. D. FELDMANN*

(*A paper presented to the Special Conference on "Cold Extrusion of Steel" organized by the Institute of Sheet Metal Engineering and held in Sheffield, November* 21 *to* 23, 1960.)

Introduction

DURING the past 10 years the cold-forging process has developed rapidly. New fields of application have opened up, and the shapes of the components are no longer attained by forward extrusion, or a combination of forward- and backward-extrusion only, but very often many other cold-forging operations have to be carried out so that the final component is no longer like an extruded part. The term cold forging—Kaltschmieden—forgeage a froid—is therefore used for a workpiece which is formed from a preform into a final shape (preform may be *e.g.* piece cropped or sawn from bar or wire, or a blank from sheet material or strip), through several cold-forming operations. However, due to the properties of the material or the nature of the operation intermediate heat and surface treatment may be required.

Cold extrusion, on the other hand, is a term used for a certain operation, which is usually incidental in a sequence of operations (Fig. 1). Nowadays cold forging competes with other production methods, especially with hot forging and machining. Cold forging is the production method of the future, because it saves material and production time and therefore production labour. It is not so universal that it will be able to replace other competitive methods completely, but it will take over part of them and become a new economical production method for certain operations.

The cold-forging process is still in its infancy and there is a good outlook for further possibilities of its application. Fig. 2 shows the increasing demand for cold-forged components based on statistics and estimates in Germany. In other industrial countries like the United Kingdom, U.S.A., France and Russia the increase appears to be much the same, but is not as steep and the steel quantities used are lower. This may be explained as follows: Before and during world war II German industry employed the cold-forging process to produce munition parts in mass production, and the experience gained is now an advantage to all industry and different fields of application. U.S.A.

* Cold Forging Ltd.

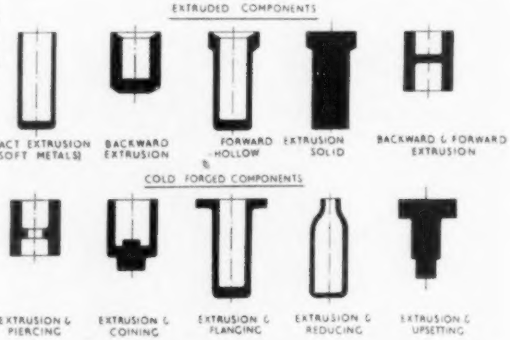


Fig. 1.

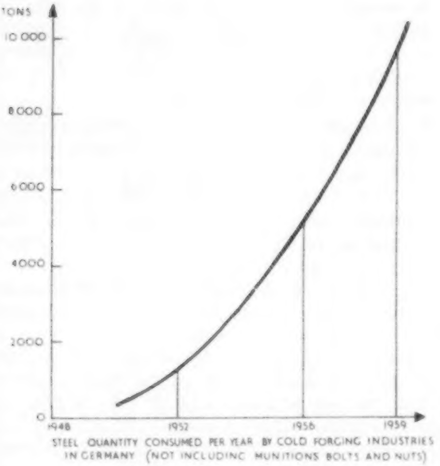


Fig. 2.

took over this experience, together with the German specialists, and employed it to produce munition and other components. Russia proceeded similarly, but with smaller investments and to a smaller extent.

France employed the cold-forging process during the war under German supervision to produce munitions. After the war some of these connexions were still in existence, especially with the Southern part of Germany, which was under occupation, and within a short time cold-forged components were produced in different industries.

The United Kingdom at first showed little interest in cold forging, and had hardly any contact with German specialists. A few tests were carried out as a result of perusal of technical publications from other countries. Some of these tests were unsuccessful. Only during the past five years, but especially during the last two years, the cold-forging process has progressed in the United Kingdom.

Economic Production Quantity

Cold forging is the method for mass production. The greater the quantities are, the more economical it is. In the case of smaller quantities, the organization, especially the tool change, has to be prepared very carefully. Fig. 3 shows the proportionate costs in the case of a single component as an example.

Of course, these costs are dependent on shape, tolerances and material of the component as well as on the existing machines and equipment. Differention must be made between special installations for production of few components in large quantities, and universal installations for the

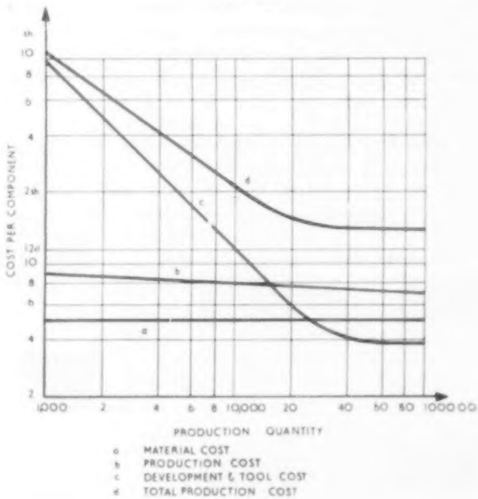
TABLE I

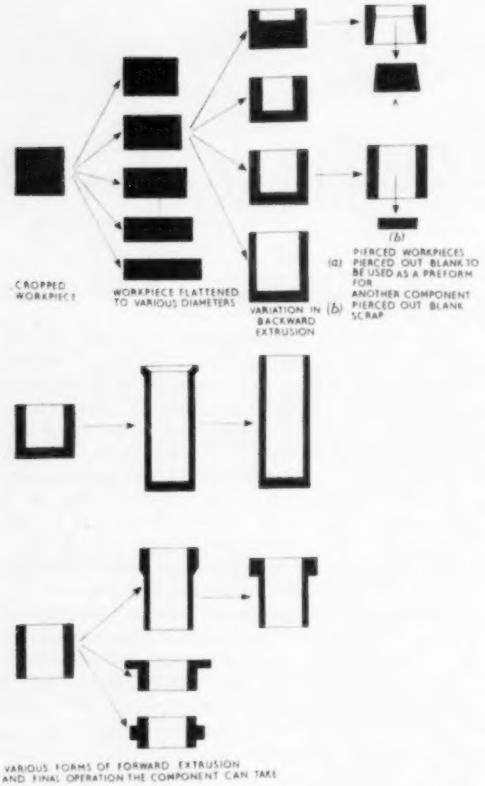
Weight, approx.	Universal installation	Special installation
	Min. number of pieces	Min. number of pieces
0.035 to 0.70 oz.	10,000	500,000
0.70 to 17.5 oz.	5,000	200,000
17.5 oz. to 22 lb.	3,000	100,000
22 to 77 lb. . .	1,500 to 10,000 according to shape	50,000 according to shape

production of smaller quantities of many different components.

Table I shows the minimum quantities for the different types of installations. But these depend also on the material and the shape of the component, and therefore there will be exceptions. Experience has proved that very often, too small quantities inhibit the application of the cold-forging process. Therefore, the standardization of components, even of different firms, can improve this, as is increasingly done in the United States and Russia. Europe will also have to employ these methods in order to remain a competitor to these countries. For instance, if all car manufacturers agreed to a standardization of certain parts which they all used, it would be possible to produce these parts much more economically than at present. Furthermore, the economics of the cold-forging process can be improved by means of the introduction of a system to standardize the shapes and dimensions of slugs and preforms, whereby higher quantities of these can be obtained (Fig. 4). Tool units are already used by Cold Forging Ltd., and more are being

Fig. 3.





constructed, which may be interchanged with little labour in a comparatively short time. Preparation time is, therefore, reduced to a minimum, so that a small number of components may still be produced economically with the cold-forging process.

The Present Sequence of Operations

The answer to the question of whether a component can be produced economically and therefore at a favourable cost, depends mainly on the sequence of operations. The number and nature of operations are decisive factors, which again depend on the available machines and equipment, which will be described in the author's second paper.

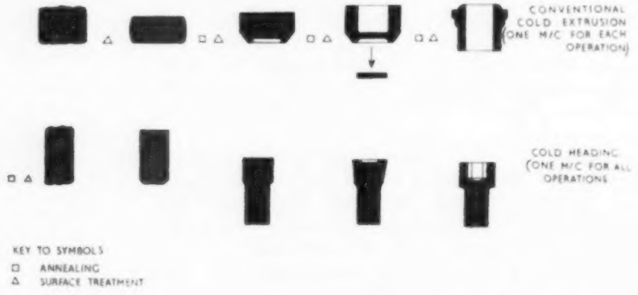
Fig. 5 shows a comparison of the sequence of operations of the well-known cold-forging methods and cold-heading methods. The conventional cold-forging method is based mainly on safety. It produces components of high quality, while cold heading, on the other hand, favours mainly quantity of production. The conventional cold-forging process uses a great number of intermediate heat and surface treatments, and there are possibilities of inspecting the components between the operations. This can be very important, especially when difficult materials are to be shaped, certain defined mechanical properties have to be obtained and components without cracks and other surface defects have to be guaranteed. The disadvantage of this method is the small production output and the high costs of the intermediate treatments. These disadvantages are not caused by the process itself but by the fact that only limited machines are available.

The cold-heading process on the other hand uses a certain number of intermediate shapes between the slug and the finished component, but there are no heat or surface treatments. Therefore, the bar or wire is usually annealed and surface-treated initially. The first operation is cropping, and here the soft annealed material very often causes crops with irregular surfaces. In the case of large diameters, there is usually a considerable burr, which has to be taken off if components of a high quality have to be produced, because this burr would cause a fold after the shaping of the material.

The cropped surfaces are without surface treatments, therefore, the lubrication on these surfaces is insufficient, even when additional lubricants are used in the machine. The surface with a lubrication carrier (phosphate coating) guarantees not only better surfaces of the finished component, but also helps to obtain longer tool life. These conditions will be changed only when

Fig. 4 (above)

Fig. 5 (right)



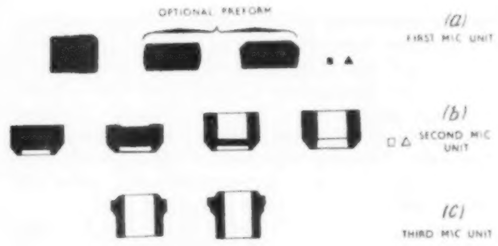


Fig. 6 (left)

Fig. 7 (below)

better lubricants are available, which have not yet been developed.

The work hardening of the material usually has to be used to its maximum, because there are no possibilities of intermediate heat treatment. This causes a certain danger, because cracking of this very hard material can be expected. In any case, a very accurate inspection has to be carried out; so it follows that the cold-forming method can be used only for certain purposes. It can be used economically for components of inferior quality and materials with lower mechanical properties. Furthermore, the shapes as well as the size of the components are limited, but in most cases components with an outer diameter below 25 mm. (1 in.) are suitable.

Mass production of hollow components often meets with considerable difficulty, since the cropped surface of the slug does not receive surface treatment, however, it is here that the main formation takes place.

Cold heading furthermore requires uniform material (initial hardness influences the final hardness), and this has been found difficult to obtain in Europe. The cold header, in addition, is a machine specialized for mass production, and is only employed when very large quantities are required, since preparation time is unusually long and production time especially short.

The disadvantages of the mentioned two methods are avoided by the COLFORG* method (also known as the Steiner process). Fig. 6:

The COLFORG method begins by producing a perfect preform on special machines (Fig. 7). If necessary, heat treatment can follow (recrystallization or annealing to obtain a soft condition of the material) and next an accurate surface treatment (pickling and phosphating) with a lubrication, this surface treatment being carefully adjusted to the requirements of the forming operation. These forming operations are carried out on Colforg special machines equipped with single or multi tools. The main conclusions can be summarized as follows :

(1) Each material, especially steel, hardens during cold forming and thereby resists further re-shaping.

(2) The degree of formation can be increased if each step in the forming process is carried out quickly, and the material is at no time left under equilibrium conditions. Operating under these conditions, however, limits the formation possibilities but not to the same extent as when the material is allowed to attempt to return to its natural condition.

(3) A certain durability of the working tools has to be reached, otherwise cold forging is uneconomical. Experience gained from mass production has shown that it is better to achieve the desired shape in several gradual stages rather than to attempt it in a minimum of steps.

(4) Economically it is essential to cold forge steel with steel tools, even though frictional conditions are unfavourable. Excessive friction is detrimental to tool life and to the surface finish of the articles produced.

It is, therefore, most important to effect favourable friction conditions:

(*a*) Lubrication of components and possibly tools;

(*b*) Use of suitable lubricants.

(5) For long tool life and well finished, accurately dimensioned articles, it is essential to exercise considerable care in the manufacture of the basic slugs.

SOME OF THE POSSIBLE PREFORMS OBTAINABLE BY THE FIRST M/C UNIT

* The COLFORG-process is based on 20 years' experience in mass production of cold-forged components and was developed in co-operation with specialists from England, France and Germany.

Determining the Sequence of Operations

Cold forging has developed so rapidly that the theory could not keep up with practice, and the sequence of operations was determined largely empirically. It is only during the last five years that cold forging has been theorized, so that to-day certain mathematical methods exist.

To-day there are few specialists, who are capable of determining the correct sequence of operations and, even so, these specialists frequently determine the sequence of operations by empirical methods. This, however, is expensive and in addition is often incorrect, since the conditions of the test equipment are different from conditions in the workshops. It is comparatively easy to develop a cold-forged component and maybe to produce several hundred, but to develop a cold-forged component so that it really can be mass produced in thousands is much more difficult. Only calculation and experience can help here.

Initial thought and calculation should be utilized and only when these are exhausted should trials be carried out.

The author's company have now produced fundamental theory from which even untrained personnel are capable of determining the initial sequence of operations. It is thus only necessary that the final stages of operations be calculated by an experienced specialist. By this means the high development costs of cold-forged components can be considerably reduced.

Economical Use

During the last few years the author has compiled many reports on the use of cold forging, some of which have recently been published in SHEET METAL INDUSTRIES. The subjects dealt with include forms which can be produced, the qualities of different steels, accuracy, hardness properties, surface finish and guiding principles for forming.

Examples have been repeatedly given by the author and others on this subject. In particular the author has always pointed out that all the examples quoted were based on mass production, where the components were manufactured in quantities of several thousands. About 150 of such cold-forged components have been made excluding those still in the trial stage.

It is important, for the economical use of cold forging, first of all to distinguish between manufacturers who produce cold-forged components for their own use, and manufacturers who produce cold-forged components for customers. A cold-forged component, which may be produced economically for the manufacturers' use, may be uneconomical if purchased by a customer, since the component cannot conveniently be re-sold. This occurs frequently when components are produced in multiple spindle automatics. The price may vary from one supplier to another, depending on the machines and equipment used, which determines the price structure.

A further distinction is between manufacturing with a special plant and manufacturing with a universal plant.

Cold forging is economical when special machines are employed for the production of large quantities of a small number of different components. Small quantities of various components, however, are produced more economically with a universal plant.

Most important is the proper utilization of the cold-forging plant. The limit, where cold forging is still economical is at about 60 per cent utilization of the plant. It is recommended to run the forging machines in two shifts, and the equipment for the intermediate treatments continuously; by this means the utmost economy is guaranteed.

Fig. 8

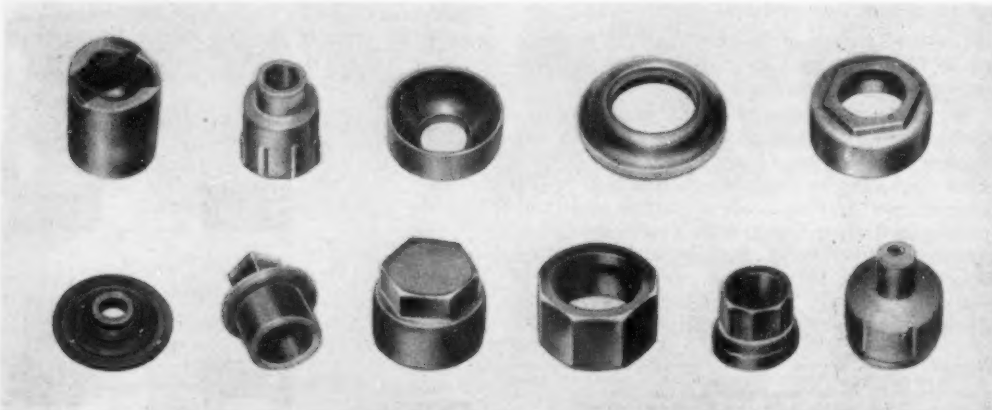


Fig. 8 shows different components which are produced by cold forging in quantities varying from 10,000 to 100,000 per month. From practical experience and from this example it may be observed that normally the investments will have equallized in two to five years; 20 to 80 per cent material may be saved, and a saving of production time of up to 50 per cent is possible. The average tool cost is up to 15 per cent of production and material cost. The tool life is calculated between 5,000 and 500,000 components produced, depending on the shape and material quality of the component.

The saving of material and production time guarantees that cold forging has a promising future.

Layout of a Cold-forging Installation

The average weight of the component, shown in Fig. 9 is the average gross weight including all scrap occurring during the cold-forging process plus 5 per cent for bar ends which cannot be cropped. The material savings in comparison with the manufacture of the components on automatic machines is 50 to 80 per cent with an average saving of 65 per cent.

Machines and Equipment

(a) *Production Machines*

1 Colforg cropping preforming machine with deburring machine for diameters up to 1 in. 60 strokes per min.

1 Colforg cropping machine with hydraulic preforming machine and deburring machine for diameters up to 2 in. 45 strokes per min.

3 Colforg cold-forging machines. 200 tons at 30 deg. crank angle before b.d.c. 60 strokes per min.

1 Colforg cold-forging machine. 400 tons at 30 deg. crank angle before b.d.c. 45 strokes per min.

6 sets of multiple tools with two sets in reserve for tool change.

(b) *Auxiliary Plant*

1 surface treatment plant. Output 800 lb. per hour.

1 annealing furnace with controlled atmosphere. Output 500 lb. per hour.

1 mechanical descaling plant with sufficient capacity to cope with the cropping machines.

Total price for the machinery and equipment specified: approximately £100,000.

Capacity of Plant

When working the production machines and the descaling plant in two shifts, and the auxiliary machines in three shifts a production of 1.7 million per month of the described components can be obtained, this output being based on an efficiency of 80 per cent for the cropping machines and 70 per cent for the cold-forging machines.

The given output of the installation together with the average weights represents a monthly production of 90 tons of cold-forged components (gross weight 102 tons).

This means:

(a) In the case of components for sale:
Based on an average price of approximately 1s. 10d. per lb. a turnover of £19,000 follows from the specified output. This turnover includes a profit of 10 to 40 per cent depending on the kind of component;

(b) In the case of the components for own use:
Cost of material for the manufacturing of the specified components from cold-drawn material on automatic machines.

280 tons at approximately £70 per ton which is the average price for cold-drawn material in low carbon production steels or case hardening qualities	£ 19,600
Cost of material for the same amount of components manufactured by cold forging from hot-rolled bar:	
102 tons at £55 per ton which is the average price for hot-rolled material of the same qualities	£ 5,610
Savings in cost of material per month	£ 13,990
Savings in cost of material per year	£168,000

Only by the saving of the cost of this material could the capital invested be regained within approximately seven months.

The following items would have to be considered as well in this connexion, but the space available here does not permit further details:

(1) Shorter production times in the case of cold forging as in the case of automatic machines;

(2) The work hardening effect of the material occurring during the cold-forging process allows in some cases, where no further heat treatment is required, the use of a cheaper material.

(3) Comparison of the tool costs for automatic machines and cold forging, whereby the cost for power and chemicals for the surface treatment and annealing operations has to be considered as well.

The given example shows a proposed outlay for a reasonably sized installation for the manufacture of a large quantity of components. For a smaller number of components in medium quantities, Cold Forging Ltd. had put together a small installation at a price not exceeding £25,000. This kind of installation has been specially designed for forms wanting to enter the field of cold forging and to start exploiting this new process with a minimum of capital investment.

EXPERIENCES IN THE INDUSTRIAL PRODUCTION AND USE OF COLD-EXTRUDED STEEL COMPONENTS

By R. E. OKELL, B.Sc., A.I.M., A.C.T. (Birm.)*

A paper presented at the Special Conference on The Cold Extrusion of Steel, organized by the Institute of Sheet Metal Engineering, at the City Hall, Sheffield, November 21-23, 1960.

THE productive unit from which these experiences are drawn is intended to serve industry in general, with the manufacture of medium-sized extruded parts up to 18 inches long and some 4 inches in diameter. It was intended to install equipment for producing components for the electrical, hydraulic, vehicle and other industries using large numbers of parts. To this end ten mechanical presses of ratings 100 to 1,600 tons with ancillary equipment were installed. Fig. 1 shows a selection of parts which have so far been produced. The flanged type of component has been found to be of particular interest.

The following account is intended to give an overall view of the factors governing the participation of cold extrusion in industrial production. Details of the process have been kept to a minimum as sufficient descriptive matter has been published to ensure that the working stages are well known, and where considered necessary a source of more detailed knowledge is indicated. Conclusions may be very different from those derived from a unit consisting of presses designed for rapid multi-stage pressing of small machine parts. In addition close co-operation with a leading German producer of extrusions has influenced the situation and German experiences have been freely used. Finally, the effect of the aim of a production shop—to produce as easily and cheaply as possible—must have a bearing on conclusions.

In order to dispel confusion resulting from the large number of names attached to the process in mind, the cold-extrusion process may be considered as the method of producing a useful article from a solid billet at room temperature by a series of cold-working operations including one or more true extrusion stages. This description gives sufficient flexibility to allow any type of operation to be inserted into a working sequence wherever its inclusion serves to approach the desired product. Hence, for example, a cylinder may be finished by cold drawing in preference to forward (Hooker) extrusion, if circumstances make the drawing operation more practicable.

The extrusion steps are essentially compressive methods of deforming and the metal is constrained to flow under almost wholly compressive stresses. Hence the limit of working which can be applied to a metal is determined by the work hardening characteristics. As the metal is worked it becomes progressively stronger until the load required to promote further movement becomes impracticably large and the loading on the tools becomes excessive. Eventually the capacity of the metal for plastic deformation becomes exhausted, and annealing is required to return the metal to its original plastic condition. In most cold-working processes, other factors become operative in limiting cold work before the limitations of the plastic properties themselves come into play. For example, the reduction which can be accomplished in a stage of drawing of a cup, is limited by the load which the walls and base of the cup can stand. No such considerations apply to an extruded cup as no tensile stresses are applied to the walls. The activating force is applied above the reduction orifice and forces the metal under hydrostatic pressure through the gap between die and mandrel.

Two types of extrusion are generally employed and they are named according to the direction of metal flow in relation to press-ram movement. An extrusion which results in metal movement opposite in direction to that of the ram is called backward extrusion, and conversely, an extrusion resulting in metal movement in the same direction as the ram is called forward extrusion. It is not proposed to go into the steps involved in billet preparation and extrusion operations as the details are sufficiently well known and have been adequately described by Morgan[1]. Suffice it to say the billet of steel must be cut from the parent stock, annealed and lubricated before work can be conducted upon it.

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Fig. 1.—Selection of parts produced by cold extrusion

Interstage treatment will also often have to be carried out.

It has been established that there are certain considerations which must be regarded if production of extruded components is to follow the desirable smooth path. Experience has demonstrated that all aspects must be planned and carried out sensibly from the beginning and the points which have so far shown themselves as important will be considered in order.

Choice and Design of Component

To a large extent the choice of component will be governed by economic considerations which will be dealt with in a subsequent section. Purely from the technical viewpoint there are limitations to shape and proportion which must be recognized. Extrusion tooling is subjected to loading approaching the ultimate which tool steels are capable of bearing and it is essential to ensure that the load is applied as uniformly and as balanced as possible. In general this consideration and problems of metal flow, limit the degree of asymmetry which can be tolerated in a given part and quantity production of unsymmetrical parts has not been found practicable. It is fortunate that the easiest shapes to produce by machining are cylindrical in section, for this fact has naturally guided most designers into employing as many cylindrical parts as possible. The cylinder is of course also the best shape for extrusion both from tool-loading and toolmaking considerations. There is no basic objection to the production of symmetrical sections other than round ; deviations merely bring complications to tool making. The effect of corners, however well rounded, cannot nevertheless be ignored particularly as they will inevitably lie in a plane which causes them to concentrate the already substantial bursting stresses.

Within the limitation of symmetry, parts may be produced bearing many useful features. It is possible to produce both hollow or solid parts with steps in diameter along their lengths. For example, variations in base thickness and configuration in the hollow parts, can result in details such as bosses or extended stems or lugs. The provision of a flange or other swelling on a hollow or solid shaft-type component is readily accomplished in most cases. Whereas a cup produced by drawing has a base and flange of thickness fairly close to that of the wall, the thickness of these features on an extruded cup need bear little relationship to that of the wall. Because of the method of production, extraction draught in the form of taper on the tools, is not required and extruded diameters are parallel except in a small number of certain special circumstances. In fact conical-shaped parts represent a special difficulty, particularly when the taper is external, for loading on the tooling increases substantially with the

slightest deviation from the parallel. Extruded parts have of course to be removed from a die and it is, therefore, important that undercuts and non-withdrawable details be omitted from the design of the blank. There is a tendency to expect to form a given part entirely by extrusion methods, but this attitude can lead to the inclusion of pressing operations of a troublesome or expensive nature to form some detail much more expeditiously provided by machining. When considering the possible provision of a certain feature, it is profitable to think of the section and strength of the tool which will produce the part.

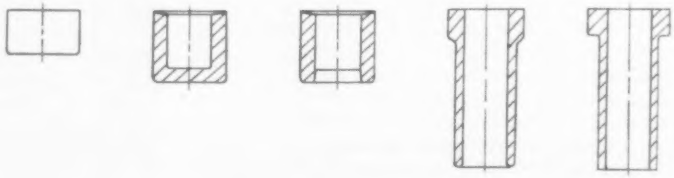
The aspect of cold extrusion which attracts the most attention is that dealing with the accuracy which can be attained and in common with most cold-working processes extrusion methods are able to produce parts close to finished sizes. However, the tolerance quoted contains both tool wear and reproduceability allowance and it has been found advisable to set a standard of allowances which give reasonable tool life and a minimum level of production difficulties. The tolerance which can be maintained on a dimension depends to a degree upon the nature of the dimension. Long cylindrical extrusions for example, can be produced to an accuracy in the bore of as little as 0.0015 in. total. This high accuracy, however, is a peculiarity of the production of this type of shape and more practical general tolerance on a diameter, internal or external of round 2 to 4 in. would be ± 4 or 5 thousandths.

If by reducing this tolerance a machining operation can be removed, then it is permissible to halve this allowance. The criterion to consider is whether the saving in machining compensates for reduced extrusion tool life, which is reflected in the component cost. The tolerance to be applied to a thickness of base or flange is controlled by variation in spring in the press frame between individual blows and a practical tolerance would be about 0.02 in. Owing to variation in size of billet, which cannot be controlled sufficiently closely to enable totally enclosed dies to be used, some provision must be made for the escape of excess metal. When a cylindrical object is being made, it is convenient to allow the excess to form extra length which is then removed by subsequent trimming. For this reason, the length of an extruded blank will not be held tightly but will usually require correcting by machining.

Design of Pressing Stages and Tooling

It is impossible in practice to divorce design of stages of working from component design, but for the sake of clarity in description it is assumed that the final extruded form has been determined. There remains the basic question of determining the intermediate forms which are to be produced in the progression towards the final shape. The method of approach has been outlined by Feldman[2] and the basis there described serves as a good starting point for the calculations necessary for the development of an extruded part. The final shape being fixed, development of a part produced in a single press operation is simple providing the component has been correctly designed. For more complicated parts it has been amply demonstrated that the sequence can be planned with certainty only by people who have done sufficient extrusion to have acquired a sense of the behaviour of steel in extrusion tools. It is possible for a particular part to be developed by laborious trial and error methods, but such practice cannot possibly hold a place in a production shop and the first condition for serious production is the formation of a team capable of applying summated experiences to a new problem when it arises. A typical sequence of operation used for the production of a flanged tube is illustrated in Fig. 2. This part is one of the simpler types of component. The stages in an extrusion sequence should be so designed that the tool steel should not be expected to bear a loading greater than 120 tons per square inch. The part of the tool which has to carry the whole of the load unaided is the punch, and this is the part which usually fails first. Friction between punch and billet is reduced by the use of an extrusion lip on the punch which results from the relieving by grinding back of the punch shank. The steel most used for extrusion punches is the 2 per cent C. 12 per cent Cr. type which is hardened to 62/64 Rc. The prime failing of a backward extrusion punch comes from upsetting of the stem after prolonged use. The barrelling effect causes the extruded billet to grip the punch stem which causes additional tensile stress to be imposed on withdrawal. This effect leads to gradual fatigue failure and shortens tool life. The greatest need in extrusion tooling is for a punch material which will bear greater loading without upsetting, for any increase in stiffness of punches would enable longer extrusions to be made in one

Fig. 2.—Extrusion of flanged tube



operation, or more drastic reductions. At present an extrusion punch must be limited in length to about three times its diameter and further depths must be attained by extra operations. It might easily be considered that one way to reduce punch loading would be to angle the nose of the punch to facilitate penetration and indeed a pointed punch does enter the billet easier. The inevitable snag is that the pattern of internal metal movement alters and instead of metal proceeding from the centre of the billet into the walls of the cup, it moves from immediately under the punch, skids over the nose and proceeds to destroy the lubricant layer. Heavy frictional loads soon wreck the tools. In effect with a flat-nosed tool, the working nose is the core of dead metal which precedes the nose of the punch itself. When this zone comes into contact with the bottom of the die complications in flow ensue and cracks between inner and outer walls follow. As a rule of thumb it is useful to aim for a minimum base thickness equal to that of the wall.

Conditions are somewhat easier for the die as it is not constricted for room and the stresses brought about by working can be partially cancelled by imposing compressive stresses through the agency of reinforcement rings. The required stresses are engendered either by shrinking parallel rings on to the die or by driving taper seating rings. Both methods have their advocates. From the production viewpoint taper seatings have the advantage in speedy assembling and dismantling. At all events the important thing with dies is to provide adequate reinforcement and providing this is done, the limitation to die life is wear.

Steel for Cold Extrusion

When producing extruded parts on an industrial scale it has been found essential to take advantage of the heavy reductions possible between interstage annealing and surface treatments. Coupled with this requirement is also the necessity for the working life of the tools to be economically long. These conditions dictate that the metal being extruded must have a high plasticity which is characterized by the resistance to deformation rising only slowly with increasing degrees of working. (*See* Fig. 3.) Such a plastic behaviour allows extensive reduction to be accomplished before either the metal ruptures or the tools become overloaded. Metals or alloys not showing the desirable plastic properties can be extruded but increased cost for extra stages of reduction and preparatory treatments reduce the economic attraction of the process.

The steel which fulfils the requirements of cold extrusion is aluminium-killed, plain, low-carbon steel, and for most general purposes this steel is chosen. Excess aluminium is added to suppress undesired strain-ageing effects so that extruded

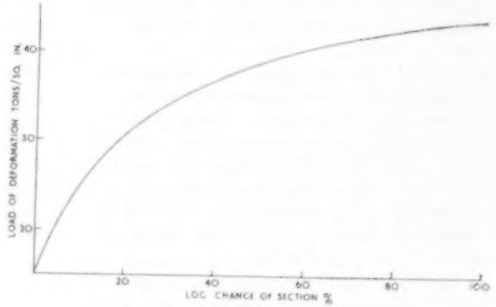


Fig. 3.—Flow curve of low-carbon steel

parts may be used at the higher strengths brought about by severe deformation. When an article is to be carburized, the carbon carburizing steels are employed instead of aluminium-killed steel in order to avoid risk of abnormality giving rise to soft spots in the case. The carburizing treatment causes recrystallization and renders the strain-age suppression by aluminium superfluous.

Apart from plain-carbon steels, certain low-alloy carburizing steels are capable of being extruded. Elements which have a strong carbide-forming character, such as chromium, can be effectively removed as carbides from the matrix of the structure and in such a form do not effect the plastic properties of the steel to the same extent as those which persist as solid solutions in the ferrite. Experience indicates that the nickel content should be held below 0.75 per cent if it cannot be avoided. Examples of steels which are reasonably amenable to extrusion are those of the SAE 4100 and 5100 series, EN 201 and to a lesser extent the low nickel chromium molybdenum steels SAE 8600 range and EN 361. With these alloy steels it is advisable to reduce the degree of reduction and hence the loading on the tools.

Preparatory Treatments

The foregoing sections have dealt with the factors which have to be considered before production begins. Preparatory treatments of extrusion billets have the objects of bringing the steel itself into a condition suitable for plastic movement and to prepare the surface with a lubricant sufficiently tough to withstand the heavy pressures without rupture. Various systems of metallic and non-metallic lubricants have been investigated. (Hautmann)[2]. The importance of the preparatory and interstage treatments cannot be overstressed.

The first steps of billet preparation is that of annealing. When deformation is only light, annealing can be dispensed with. This is often the case if a preliminary sizing—squaring operation is part of the sequence, and the subsequent annealing

benefits from the cold work. In general, however, it is unwise to attempt heavy cold work on a hot-rolled structure. Plain low-carbon steels are sufficiently well annealed by a sub-critical softening treatment preceded if necessary by a grain refining normalising treatment. Subsequent interstage annealing is also sub-critical and results in recystallisation. When more difficult steels are to be pressed it has been found necessary to aim at the production of spheroidal cementite with the maximum removal of alloying elements including carbon, from the ferrite.

Such annealing treatments are one of the reasons for the comparative scarcity of cold-extruded components in anything but low-carbon carbon steels since annealing costs play a significant part in the cost of production, which in the end decides whether a part becomes the object of large-scale production or remains a curio piece.

The success of extrusion of steel depends upon the provision of a tough tenacious lubricating layer separating tools and extruded steel. As soon as this layer is ruptured, tool wear accelerates to a level unacceptable under production conditions. In addition, extra loading to overcome increased friction is imposed upon the tools, and flow of the steel is hindered giving rise to undesirable effects. It is clear that the preparation of the surface of an extrusion is of great importance.

The lubricant system used in practice is a crystalline phosphate coating coupled with a soap lubricant which is reinforced on occasion with molybdenum disulphide. This system, applied conveniently through the agency of proprietory solutions, has been found to give good results providing that the coating baths are kept in good condition. The results of poor phosphating are not always immediately apparent and similarly it is not always obvious that a given coating with its lubricant is deficient. The tests available do not seem to give much guide to the serviceability of a coating. In the press shop the lubricant is judged by looks, feel and performance on the press, which under present circumstances seems to be the best criterion even with the variations due to individual opinions. A simple accurate means of assessing coating quality would be a welcome development.

Use of Extruded Parts

The actual pressing of extruded parts has no special difficulties of which press operators in general are unaware. Press development work has to be carried out, but once the tools have been established complications are few, and the extruded parts become available for use. There are two main divisions of interest in the factors influencing the use of extrusions. One of these is the properties of the part and the other is the economic attraction of the process. The two features are not completely separable.

Apart from forming steel into the desired shape cold-extrusion methods produce effects on the properties of the steel as a consequence of the drastic cold working. The work-hardening properties of a steel can be used to increase its strength without resorting to heat treatment. A severely worked low-carbon steel can exhibit a strength of over 50 tons per sq. in. but for design purposes it is preferable to aim for 40 to 45 tons per sq. in. Providing a steel of strain-age-resistant quality is used, there is no detrimental embrittlement developing with time in a heavily worked piece. As a further precaution, and also where it is desired to increase ductility, a special stress-relieving anneal can be applied as a final operation. This has the effect of relieving the internal stresses and provides the possibility of more plastic working—in other words increases ductility. In the extruded condition a low-carbon steel is capable then of replacing a heat-treated medium-carbon steel. In practice it is found advisable to compare yield stress figures rather than ultimate tensile strengths, for the yield stress of a cold worked steel approaches the ultimate stress nearer than in the corresponding case of steel heat treated to a given hardness. By the use of work hardening it is thus possible to develop the properties of a through hardened steel, but the useful response of a medium- or higher-carbon steel to surface hardening treatments involving differential heating, is still lacking. If an induction or flame-hardened surface is required a cold-extruded part suffers a disadvantage.

Cold extrusion does not alter the basic nature of a metal in any way. That is to say : take away the one effect of drastic working, which is an increase of strength, and the metal still has its normal attributes. A steel will respond in the well-known manner according to its composition to a thermal treatment. Normalize or anneal a low-carbon extrusion and it will be once again soft mild steel. Carburize an extrusion in EN 32A and EN 32A expected properties will be obtained. Many thousands of parts have been carburized and distortion has been found to be low and uniform, and it has also been found quite in order to omit the normalizing treatment which often precedes the case hardening of hot forgings. The reasons for normalizing are twofold : to allow any distortion which is going to take place to occur before final machining and to refine the large grains resulting from high-temperature working. With a cold-worked component there are no coarse forging grains and distortion will be well within the normal grinding allowance.

There is a difference between the surface of an ordinary machined part and that of an extruded one, and that is the phosphate layer which has been

compressed into a hard shiny skin. This skin is not to be confused with the surface layer on some forms of metal shapes which ruins cutting edges but nevertheless it can be a nuisance, not so much to the machinist but for other operations. Welding, soldering and brazing are hindered by the phosphate and at least local removal is essential before using these joining methods. Complete removal can be effected by acid or alkali pickling with very little alteration to dimensions. Mechanical methods can also be used, and it can often be arranged that the trimming to length of a tubular component can be used to prepare, say, an area for butt or seam welding. It is important when welding to allow for the fall in hardness which inevitably accompanies heating above recrystallization temperature. In this respect the extrusion fares no worse than the heat-treated structure which will be overtempered around the weld and can also quench itself to give rise to a hard zone in the heat affected area.

A similar condition to that applying during welding occurs with hot-dip plating, for the phosphate effectively prevents metal-to-metal contact and must be removed. In one application the barrelling operation which removes a sharp corner also serves to prepare the surface for plating with complete success. Electroplating is also impossible before the phosphate is removed. On the credit side, the layer has a certain protective power against corrosion, either alone or reinforced with an oil seal or lacquer and storage benefits from this protection. Wear resistance of a surface is also improved and a useful increase in the life of hydraulic cylinders has been recorded after a change to extruded cylinders with phosphated bores. The surface of an extruded part is clean, scale-free, extremely smooth and free from decarburization. Etched sections show that the grain flow follows the external form closely, and since the blank is so close to the final form, finish machining operations do not seriously interfere by severing the flow lines. It is often the case with normal hot forgings that removal of draft and allowances exposes stress raisers in the form of inclusions which can decrease fatigue life. Several instances of improvement in fatigue life have been noted when extruded parts have substituted parts machined from the solid or from forgings. The improvement has been attributed to the favourable grain flow, excellent surface bearing no circumferential tool marks, lack of decarburization and the system of surface stresses remaining in the walls.

Experience has shown that certain well-defined facts have emerged which govern the applications of the products of a general extrusion plant. The process is not so often accompanied by such vast savings that it automatically ousts all competitors. It is necessary to select suitable components and to attempt to incorporate as many advantages as possible into the extrusion design. Final cost rather than cost of extrusion compared with its equivalent in other semifinished forms should be considered.

The main items of credit in the economic balance for extrusion techniques are (1) saving of material, (2) saving of machining times, (3) the ability to produce readily, certain features which are difficult to form by other methods. In favourable cases extrusion methods are capable of using up to 95 per cent of the metal presented in bar form. This high figure is only rarely achieved but nevertheless the general degree of conversion of raw material into useful form is substantially higher than with competitive methods. Included in the saving must be the gain brought about by upgrading the low-carbon steel without heat treatment. There is a great temptation to chase material saving too far and to spend more on operation costs than the material is worth. The extrusion designer must temper his ingenuity with common sense and cost calculation to ensure that the cost of a step designed to save material does not exceed the cost of the material plus the time to machine it away. A consequence of this reasoning is that the production of large quantities of small simple cylindrical parts is likely to remain the domain of the multispindle automatic. The reason for this is that the limitations of the cold-working method usually ensures that some second-operation work will be needed to produce the required part from an extruded blank. Handling time can quite easily cost more than the saving in metal.

The situation alters when a shape is required which cannot be achieved on a single setting from a bar auto, for then the extra setting operations can be used to complete the extruded blank. Such a part may have, for example, a bore whose section requires to be broached or requires milled flats on the periphery. Both of these features could conceivably be extruded, leaving some simple turning to complete the part. Unless some factor of this nature is present, extrusion is not likely to compete with high-speed bar machining methods if carried on ordinary general-purpose presses. It has been shown possible to compete on automatic multi-station presses which are then the press man's equivalent of a bar auto. Such machines are expensive and must be reserved for the production of a very few items needed in extremely large numbers.

In a similar manner, the material saved when producing a simple shallow cup from a solid slug instead of from sheet metal does not pay for extra work needed to make the cup. Whereas the strip has already the required thickness of wall, work must be applied to the slug to reduce it to this thickness. Extrusion methods overcome this factor as the proportions of the cup change and its complexity increases. For example, the wall may

be too thick in relation to diameter for cupping of strip, or any of the variations of wall thickness, base and flange, previously outlined may be required. The comparison also becomes modified as the depth of cup increases and the advantage of the heavy reductions which extrusion makes possible overtakes the initial ease of forming.

Coupled with the saving in material is the saving in the time of removing the excess. In very favourable cases the extruded blank is cheaper than the equivalent forging or length of bar-stock, but often we have to look for savings in machining time to swing the balance in favour of extrusion. The highest degree of saving comes from incorporating a feature which cannot be formed on a lathe and, next to this, the provision of a deep bore when required. It follows from this that one should seek for the most expensive machining operation on a given part and attempt to produce the required feature even at the expense of the other details if necessary.

Since deep holes are expensive to bore and are also rarely produced in preformed blanks, there is a tendency to find that hollow shapes lie especially in the field of economic working, particularly as a deep bore is usually accompanied by high material loss. In such an instance material and machining savings are coupled to give optimum return. In order to realise the maximum savings which can be achieved it is important that the designer of a given part and the extrusion technician get together and discuss the part in relationship to the whole assembly for it is often the case that assemblies can be made as one piece thereby eliminating welding or other fastening method. In some instances it is found that the original proposed replacement has been quite uneconomic, but after adding certain easily incorporating amendments which make ancillary details redundant, the cost has become attractive. In other cases a part may be possible of form which would be prohibitively expensive by other methods.

Concluding Remarks

An attempt has been made to condense the experiences gained in the industrial production of extruded parts. Used in its proper field, the cold extrusion process is a valuable production tool for the engineer and takes its place with other methods of manufacture. Providing care is taken to recognise the limitations as well as the advantages, application of the process can lead to useful easing of many problems together will economic gain.

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DISCUSSION

of the two foregoing papers

Mr. F. Griffiths (British Motor Corporation) said that he wished to join issue with Dr. Feldmann on the way in which he had deduced the cost factors shown. He had assumed in the paper that for a given number of components the cold forging material usage was 90 tons compared with a normal usage in industry of 280 tons (*i.e.* producing the components on automatics). This was quite wrong. Throughout the world the average wastage in the consumer industries was ton for ton. In some of the more accurate basic processes it was less than that. In the most wasteful—the bar automatics—it was only 2 tons wastage to 1 ton of finished material.

Dr. Feldmann was proposing the use of six units of capital equipment costing £100,000. His own considerable experience suggested that this was four times greater than it should be. That fact would have a severe effect upon the economics quoted.

The 70 or 80 per cent figure given as the desired efficiency for plant was very arbitrary. His own analysis of efficiencies in industry had revealed that the great loss was in change-over and not in getting the right material at the right place at the right time. In fact the actual efficiency of capital equipment was nearer 97 or 98 per cent. Therefore, he did not see that a cold-formed component made by a supplier should necessarily be any different in cost from one made by the user, except for the nominal 10 to 15 per cent profit that was normal in industry.

Mr. Drewery (English Steel Corporation) said that Dr. Feldmann had referred to a mathematical method of assessing the stages in production that a cold-forged component should go through : that a semi-skilled draftsman, or someone similar, could be trained to go through the stages in the calculation and show how a cold-forged component could be made. Could he explain the method more fully?

Dr. Feldmann said that the method was based on his book, published in Germany and due to be published in the spring in England also. It gave the fundamental theory for the cold forging or cold extrusion process. The question was too extensive to answer at the moment.

Mr. Drewery asked what was meant by the fundamentals. Was it a sort of basic plasticity theory?

Dr. Feldmann : Yes.

The Chairman (Mr. A. E. Gilbert) referring to a film shown by Mr. Okell after the presentation of

his paper said that five or six years earlier some members had taken part in a tour which had included a visit to the plant shown, in Germany. They had questioned the absence of guards and had been told that they interfered with production. They had asked, "What happens when you have an accident?" and had received the reply, "We just get another operator!"

Size of Presses for Cold Extrusion

Mr. HARRIMAN (Raleigh Industries) said that Mr. Okell had mentioned that he had a wide range of presses. Would he discuss the size of the component, and say at which point it might be advantageous to go to hot forging? Presumably one could go on for ever with bigger and bigger presses, but there must be some point at which it became uneconomic.

Mr. OKELL replied that it depended on the individual part. As the size went up the quantities required tended to come down. This factor came in, quite apart from straight technical comparisons. His company were extruding articles of about 4½ in. diameter on a 1600-ton press and found that although costs went up in proportion to size the average costs went up quite a bit more. With the very large sizes, the material left on forgings for machining was even greater than with the smaller sizes. One tended to get rather rough forgings, of 4 or 5 in. in diameter, and this helped one to make a profit on extrusions.

He did not think that capital cost would allow the use of a press of more than 2,000 tons capacity. This would produce a component of 5/5½ in. diameter. It might be very difficult to find sufficient work to keep the press operating.

Mr. J. McKENZIE (N.E.L.) remarked that the film which was shown appeared to be a sound film and run at a slower speed than that at which the process filmed was taking place.

Mr. OKELL said that there was no sound track on the film. The plant was actually slow-moving and pains had been taken to ensure that the cameraman got all the detail necessary.

Mr. J. McKENZIE asked whether Mr. Okell's organization used operating speeds similar to those shown.

Mr. OKELL said that it did not; that in production it had been found that the speed of extrusion, within ordinary press limits, did not have a great bearing on the extrusion itself. Backward extrusions were made at the rate of 30 a minute, and he would not worry greatly about exceeding this. Extrusions were also made very much slower than this.

Mr. R. A. P. MORGAN (R.O.F. Birtley) asked for Mr. Okell's experience with regard to low- and medium-carbon steels, and whether the steel he received was of the quality desired.

Steel Quality

Mr. OKELL replied that no user ever had steel of the quality he desired. The steel which was available was not always round, within the required tolerance, or free from surface faults, but apart from these physical defects it was satisfactory.

Mr. R. A. P. MORGAN asked whether it was not a fact that a great deal of trouble could arise when expanding a flange—25 or 40 per cent—because of splits, and that as a result down-time and wastage were both higher, and therefore cost of production was much higher.

Mr. OKELL said that he did have trouble with the expanding of steel. It was a difficult question, so far as flanging was concerned. It was necessary to make do with the steel available and to impress upon the steelmakers that they would like something better than they had been used to for ordinary hot forgings since they had not the advantage of a furnace to remove surface by scaling in the drop forge. His company made a good many drop forgings.

It was normal practice to put steel on the hammers which looked seamy when offset or pickled. What came out were relatively good forgings surprisingly free from surface seams. This could only be as a consequence of scale loss and therefore scale-free heating might produce a lot more trouble.

As regards cold extrusion it was necessary to attempt to get better steel and/or to sort out steel for certain jobs, or attempt to ensure that the seams came in the place where removal was to take place. For this reason an attempt had been made to put quite a lot of excess material on the outside of the flange.

Mr. J. GAULT (Walter Somers Ltd.) asked for Mr. Okell's experience in Birmingham on the type of die steels used in connexion with the tooling for the various components on exhibition at the Conference and whether the range was still in high chrome-high carbon as it was in the early part of the experimentation.

Mr. OKELL replied that he thought that the paper to be presented by Mr. Comley covered the type of material being used. His company had not found some wonderful specification which gave two or three million components with virtually no wear on the die, or anything like that. This was one of the reasons why caution was exercised in the tolerances quoted. Wear did take place, and once it started on a die it tended to take place locally and became rapid. He did not want to sound too pessimistic but felt that, if only to balance the over-optimistic views expressed, a certain amount of cautious pessimism was justified.

Tool Design Stress

Mr. H. Ll. D. PUGH (N.E.L.) said that on page 3 of the paper the author had suggested that the

tooling should not be expected to stand more than 120 tons per square inch. His own experience had been that on punches for canning operations this was about the minimum stress one could expect anyway.

Mr. OKELL said that he designed so that the punch would take about 120 tons : it was a design stress figure. It was not possible to guarantee how much it would exceed that by factors over which they had no control.

Mr. PUGH said that the point he wished to make was that there was a minimum stress of punch for a canning operation which occurred at an extrusion ratio of about 2. It was twice the extrusion ratio in the normal way, and if one used anything but the very low carbon steels the punch stress would sometimes be well above 120 tons per square inch.

Further, the author said on page 6 of his paper that an increase in fatigue life had been obtained with some extruded products. Could he say what the products were, and what evidence he had in mind?

Mr. OKELL said that the point at issue was that with a hot forging there was usually up to 7 deg. draft, and quite a lot of excess material, and although the forging might of itself be a good part with ideal flow lines, by the time it reached the finished stage most of these had been cut. For instance, a pinion forging might look as if it was a good one, but by the time it had been cut there was very little left of the grain flow that was wanted, at the corners and so on.

In the case of an extrusion the finished form approached the final form much more closely. Machining was not required to anything like the same extent and there was more or less the same grain flow at the end as at the beginning. This might not have a great bearing on fatigue life until a part was made from dirty steel. Then one could have outcrops of extrusion which would lead to certain fatigue life effects.

The other point was that the surface, if left untouched, was very good, and there was no decarburization. The solid evidence that they had had on this point had come from Germany. Mr. Okell referred to a pneumatic hammer, the heat-treated housing of which was giving extensive trouble which had disappeared when a change was made to a cold-extruded low-carbon steel housing, and the fatiguing had stopped.

Mr. GRESHAM (English Steel Corporation) said that earlier Mr. Okell had referred to the quality of bar received. Was he to take it that he extruded the black hot-rolled bar? Dr. Feldmann had referred to cold rolled bar. Was it not worth while considering a machined bar for a start? Could he give any idea of how far it was possible to extrude before it was necessary to anneal prior to the next operation?

Mr. OKELL replied that, referring first of all to the bar, the main thing that one was chasing was steel. If the cost of the steel used was increased over that used by other people part of the saving was lost, and it took every effort, on some jobs, to keep the work within the price of the steel saved. Some of the black bar received was very good. Some of the modern mills turned out excellent bar, but they also had other mills which had difficulty in rolling round, straight bar within a reasonable tolerance. The steel specifications were made to fit those mills.

His company had found it better to keep to about 60 per cent reduction in area on backward extrusion in quantity production; but it was possible to increase this if it was not required to make more than 200 or so components. On forward extrusion it was possible to reduce up to 70 per cent, or maybe a little more, with low-carbon steels. With alloy steels it was necessary to proceed warily and, if in doubt, to allow an extra stage.

Mr. DREWERY (English Steel Corporation) said that when faced with the task of making a part it was necessary to decide just how many operations, and of what sort, could be done before interstage annealing and re-coating; a decision had to be made before making any dies. It was not a matter of making the first operation die and then saying, "we can get a little further than this before we anneal it". The whole operation had to be decided before starting the first die. He understood that Dr. Feldmann had written a book on this. Was he guided by the book in his die design? How did he decide the question of annealing? Was it by experience or by scientific theory?

Mr. OKELL said that this was the point that he had made earlier, in introducing the paper: that the first requirement of anyone attempting cold extrusion was to build a team of people who were able to assess what was going to happen in a set of extrusion tools. That normally meant that one had to break a few sets of tools and perhaps even stall a few presses. But even then it was necessary to work out the finer points for oneself. With a little experience it was possible to put together a sequence which would not be far off the one required. But it was essential to have the necessary experience available. Scientific theory was useful for explaining things once they had been done. Calculations were also useful, but in the end it was still necessary to put a set of tools in the press and have enough confidence to press the button. In short, there was no way round this matter of having a team of designers.

Structure of Steels for Cold Extrusion

Mr. SOUTHAM (College of Technology, Southampton) asked whether the author began with a conventional annealed structure or, in fact, created a special metallographic condition?

Mr. OKELL replied that more often than not, a start was made with a hot-rolled bar, if "they thought they could get away with it". It was possible to do fantastic things with ordinary mild steel without worrying too much about its structure. With the alloy steels it was a little more difficult. The nickel-bearing steels, particularly, showed the most disheartening reluctance to soften. His company had begun by following the practice used when working with high-carbon steels. In other parts of the works they deep-drew 0.6 carbon steel which was supplied in the spheroidized condition, and it had been thought that the best thing to do for extrusion would be to try a spheroidizing treatment. This took a very long time. Later work suggested that instead of having a uniformly distributed carbide in a matrix it would be better to keep a ferrite-pearlite structure, slightly divorcing the pearlite and making the ferrite as soft as possible, so as to have a cushion to move and carry the harder grains with it. So far as the low-carbon steels were concerned, it had been found that an ordinary sub-critical anneal was quite adequate for the severest deformations.

Mr. R. H. SPIKES (Joseph Lucas Ltd.) said that in Dr. Feldmann's book there were three nomograms which allowed the prediction of what the tool forces were with reasonable accuracy. These agreed more or less with the N.E.L. figures within the normal working range. It was a very useful guide and prevented the mistakes that had been made in the past in choosing the wrong job to begin with.

Choice of Reduction

Mr. J. MCKENZIE said that the author had said that 60 per cent might be a reasonable reduction in can, and probably more with rod. Figures were available at N.E.L.—and they would come to light during the conference—over the whole range up to 1 per cent carbon steel, which permitted the choosing of any reduction and made it possible to find out the pressures and stresses, hardnesses of material, etc., in fact, there was nothing not known now in the cold extrusion of steel. It was not really as big a mystery as Dr. Feldmann and Mr. Okell had appeared to indicate.

Mr. OKELL asked Mr. McKenzie how many extrusions he had made from one set of tools.

Mr. J. MCKENZIE said that he had gone up to an extrusion ratio of 12, which was 92 per cent reduction. As might be expected, they had broken quite a few tools. Not being a production laboratory, they could not give any details on tool life.

Mr. OKELL said that this was the whole point. His own organization produced at the rate of 50,000 a week and based their ideas on things which succeeded over a long time. It was found that little things meant a great deal in tool design and it was preferable to err on the safe side until the first 50,000 or 60,000 components had been made. If there was any room for development after that it was possible gradually to make changes. Despite all the figures that had been obtained by testing there was a good deal of "mystery" still about the art of producing cold extrusions in quantity, and of producing something to design for a price. The latter was very important to people who made their bread and butter on production.

Mr. J. MCKENZIE agreed that tool life was the biggest mystery of all, and that no-one knew exactly how the tool would behave, but the question raised earlier had been as to how one would produce a certain product. This could be done quite readily. One could not guarantee how many components could be had from a certain tool, but could give the best conditions at which to extrude, thus ensuring the best tool life that could be expected in relation to a specific product.

Mr. OKELL said that if one was talking about simple things like cans a production sequence could be laid down fairly readily, but he was thinking of he situation in which a customer came along with at complicated product from the extrusion point of view. Preform shapes were very important in this type of job and it was not possible to draw them up from the technical figures available. It was necessary to develop a sense of "feel"—a sense of what would happen when one made contact on a certain preform with a follow-on tool. There was also the matter of tool design. The preform and the tool design were coupled to ensure that the tools were robust and the preform would turn itself into the next shape when it was processed with the next tool. This was where the scale of the job came in. Apart from the simple shape "feel" came into the process very much indeed. In one of the N.E.L. papers it had been said that it was not possible to extrude a conical shape. He could produce one, but predicting from what had been done before what was going to happen next was rather difficult.

Dr. J. WALLACE (University of Sheffield) offered a warning about the use of nomograms and basic figures in calculating extrusion loads. As most people knew, the extrusion pressure consisted of two components—the pressure required to do the homogeneous work and that required to do the redundant work. The amount of the latter depended upon the component being made and how the metal had to flow from the preform to the next stage, or from that stage to the one following, and the results obtained were only for one degree of redundant work. If the component was changed the degree of redundant work would be smaller or greater. This was where the experience of the tool designer came in—in minimizing this factor so that it was possible to obtain the maximum extrusion ratio with minimum extrusion load.

Adiabatic Conditions

The conference would have noted the steam, or smoke, rising from the extrusion operation shown in the film. Did the heat facilitate the extrusion in any way? Did the deformation take place under so-called adiabatic conditions, thereby affecting the stress-strain characteristic? Did the author feel that warm working—the addition of a certain amount of heat to begin with—had any very advantageous effect?

On the question of fatigue, when an extrusion was produced certain planes were subject to very high shear and distortion. In the cold-extruded form these planes might be completely annealed. Alternatively, with heat treatment, a different type of grain growth occurred in these regions. Had the author any experience of this causing trouble in regard to fatigue life? Also, an extruded component usually had a very high surface deformation in comparison with the core. This meant that in the extruded state the surface was probably harder than the core, which would automatically produce an increase in fatigue life.

Mr. OKELL said that there was evidence, in regard to the stress system remaining in an extrusion, that the surface was very subject to residual compressive stresses which would be expected to have the same sort of effect as those induced by shot peening, induction hardening, case hardening and similar treatments which were known to affect fatigue life. He had never had a part which had been so strongly worked as to develop enough heat to anneal itself. Although some very heavy reductions were made at times the extruded part was always hard. He felt that the heat developed by extrusion facilitated work in the latter stages, and he had a suspicion that this was the reason for the drop in press loading as extrusion proceeded. Mr. R. A. P. Morgan, in a paper to the Iron and Steel Institute had given the results of experiments in heating to various temperatures around the 200° C. mark, and the drop in extrusion pressure achieved.

Some advantage might well be gained by preheating the slugs to temperatures below the breakdown point of the lubricant although he had no experience of this. For the last 18 months his company had been producing cold extrusions, designing tools and so on, and had had no opportunity for further work, but eventually he thought they would have to do so, if only to extend the range of extrusions which could be produced with the plant to hand.

Mr. J. F. KAISER (Gillette Industries) expressed surprise that papers on the cold extrusion of a metal should so often fail to say very much about the physical properties of the metal being extruded. The author had said that he just accepted it from the mill. Had the bars used been rolled out into the open, or put one on top of the other? It made an enormous difference to the properties of the steel. If one was only considering jobbing work it did not matter, but he had never been associated with production that entailed less than say 10,000 items a day. It had been understood that tools were always worked until they were finished and he felt that the physical properties of the material wanted should be specified.

No-one had exploited more than he had the principle of "suck it and see", because it was often quicker than the scientific approach; however, a more scientific approach was now possible. Could not cold extrusion be approached from the point of view of the real, logical properties of steel, in particular taking cognizance of the fact that in the case of many metals cold working led to an increase in volume? The specific gravity went down and this had an effect that had to be considered. Some people disputed it but it was nevertheless a fact. If one submitted a very large number of things to a stress that entailed a shear in any sort of weather one got the phenomenon of dilatancy, which led to an increase in volume. Had the author taken cognizance of that, and if not why not?

Mr. OKELL said that he did not pay any regard to the increase in volume during extrusion. In any case, it was removed by pickling.

Mr. KAISER said that it was utterly impossible to alter the specific gravity by pickling. He thought that Mr. Okell had rather missed the point.

Mr. OKELL said that he did not take it into calculation at all. So far as the physical properties of material were concerned, he asked the steel producers to provide straight bars and round bars to within a reasonable tolerance, free from inclusions and to the right specification. He would take any structures that they were given, as it was easy to put that structure into the condition required. It was not possible, however, to take out seams, make bars round, etc., except by extra work that no-one wished to pay for. The same applied to the removal of inclusions. The structure was not regarded as being particularly important because it could be corrected by heat treatment.

What happened to them after they came from the mill did not matter a great deal so far as the effect on extrusion pressures was concerned. With alloy steels it would make a difference but alloy steels were not processed until they had annealed them themselves.

Mr. KAISER said that Mr. Okell had still not mentioned a word about the physical properties, such as tensile strength, in the material as used.

Mr. OKELL said that they put the steel into a condition that was as soft as possible within the right price bracket. This meant that low-carbon steels received sub-critical annealing or, if necessary, a grain refining normalizing treatment followed by a

(*Continued on page* 56)

A STRETCH-FORMING TEST FOR USE WITH A VARIABLE-SPEED DRAWING PRESS

By D. V. WILSON, B. B. MORETON and R. D. BUTLER

(A paper presented at the recent Paris Meeting of the International Deep Drawing Research Group and the Société Française de Metallurgie.)

IT is suggested that, while stretch-forming tests have a potentially important role as simulative tests, designed to predict material performance in sheet-metal forming, in some respects further development is needed to meet this requirement. A test developed at Birmingham University, which can be carried out on a Swift drawing press, is described. This uses a standard 2-in. (or 50-mm.) diameter hemispherically-headed punch and allows a choice of penetration speeds up to about 100 ft. per min. Experimental results are presented which illustrate some of the advantages given by the large tool and the variable forming speed. A method of rapid testing which eliminates the necessity for stopping the punch at the exact moment of fracture is described.

I—Introduction

AT present the potential usefulness of simulative tests, in predicting material performance in sheet-metal pressing, is unchallenged by more rigorous analytical approaches because of the complexity of the latter.

It is comparatively simple to devise simulative tests which will, in effect, solve the equations relating performance to the plastic properties of a material, for a particular set of conditions of applied strain and frictional restraints. The difficult problems are met in judging the relevance of this information in diverse conditions of practical presswork. In the case of complex forming operations much careful experimentation and analysis remains to be done before sufficiently reliable predictions can be made from the results of a small number of standardized tests.

Recently good progress has been made towards testing, on an adequate scale, the predictions of cup-drawing tests against performance in production. In the case of true deep-drawing operations, the value of a cup-drawing test of the " Swift" type(1) is already evident : the problem is now that of assessing the relevance of its results to the wide group of forming operations which combine the elements of deep-drawing and stretch-forming. The scope of the " Swift " test is extended into this field by using a hemispherical (or even an ellipsoidal), nose form on the punch. However, while considerable stretch forming over the punch head is achieved in these ways, performance is still judged in terms of the limiting drawing ratio. Thus the test remains a deep-drawing test concerned, essentially, with the ability of the stretch-formed region to support the drawing load. Improved lubrication on the punch, for example, will generally reduce the measured performance, although it may promote more uniform stretching over the punch head(1, 2).

For this reason " Swift " test results (assessed in terms of the limiting drawing ratio), may be more restricted in their useful application to operations in which stretch-forming is an *essential* element of deformation, than was at one time hoped. For example, the Swift test is criticized because it is rather insensitive to the loss of ductility which accompanies strain-ageing in temper-rolled steel sheets. This change of properties seems to be a proven cause of trouble in many important types of sheet-metal forming which involve stretching. This is not a valid criticism of the test but rather of its application.

The additional information required in such cases is evidently of the type provided by stretch-forming tests, in which the criterion of performance is directly related to the ability of the metal to sustain biaxial extension without fracture. Such a test can be regarded as complementary to the cup-drawing test.

II—Stretch-forming Tests

The earliest simulative tests to receive general acceptance—notably the Erichsen and Olsen tests—are of this type, but in recent years far less effort appears to have been devoted to their development than has been the case with cup-drawing tests. Although of proven value, small stretch-forming

tests have a number of limitations which can restrict the quantitative significance of their results. For example :—

(a) Consistency and Reproducibility of Testing Procedure

Results may depend too much on the operator's skill and judgment. Careful standardization of clamping conditions, lubrication, forming speed and judgment of the end point is required to give consistent results. In principle most of these limitations have been overcome in some recently developed versions of the tests, in which judgment of the end point can be made automatically. Clamping conditions vary in different versions of the test. If stretch-forming tests are to be used to supplement, rather than substitute for, deep-drawing tests there is a good case for minimizing the draw-in of peripheral material.

(b) Size of the Test-piece

The area of material tested in existing stretch-forming tests is often quite small and the use of a small punch, commonly of 1 cm. nose radius, means that the area suffering large strains is localized, also, in the case of thicker sheets, considerable bending strains are superimposed on the biaxial stretching. Effects of these characteristics are examined in (*c*) and (*d*).

(c) Effects of Sheet Thickness and the Contributions of Necking Strains

Possibly of more general importance than the sample size limitations associated with the use of a small tool, is the fact that tests of the Erichsen type may fail in their role as simulative tests (particularly with thick sheets) because disproportionate importance may be given to necking strains or to performance in bending under tension. Table I gives some results of Erichsen tests, made

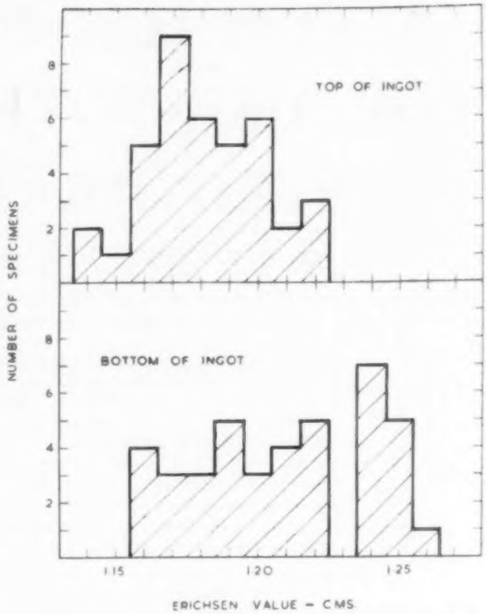


Fig. 1.—Variation in Erichsen values for temper-rolled sheets taken from the top and bottom of a rimming-steel ingot

on aluminium and Duralumin sheets of three thicknesses, in which measurements of local strains were made by means of photogrids applied to the sheets before straining. These results show that, with ductile materials, strain in necking makes a large contribution to the total radial strain obtained in Erichsen tests taken to the point of fracture. This effect becomes more dominant as sheet thickness increases (due to the fact that a constant

TABLE I

Material	Thickness (in.)	Erichsen value (mm.) (Mean of three tests)	(a) Mean radial strain on outer surface of dome. (Measured over 1.25-cm. radius from pole)	(b) *Proportion* of total extension (*a*) occurring in a 0.25-cm. wide ring which includes neck	Approximate stretch per cent in (*b*) (0.25-cm. wide ring including neck)
			Per cent	Per cent	Per cent
Commercial-purity aluminium (annealed)	0.60	12.6	39	58	114
	0.30	10.9	31	55	86
	0.15	9.3	25	46	58
Commercial-purity aluminium cold rolled 50 per cent	0.60	9.9	28	64	90
	0.30	7.8	21	61	64
	0.15	6.0	15	54	41
Duralumin, fully heat-treated	0.60	5.6	12	44	27
	0.30	5.7	—	—	—
	0.15	6.0	14	48	33

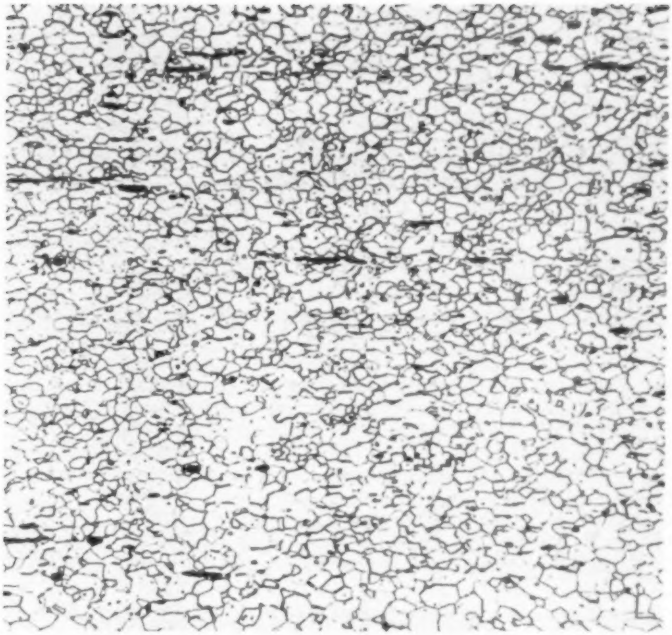
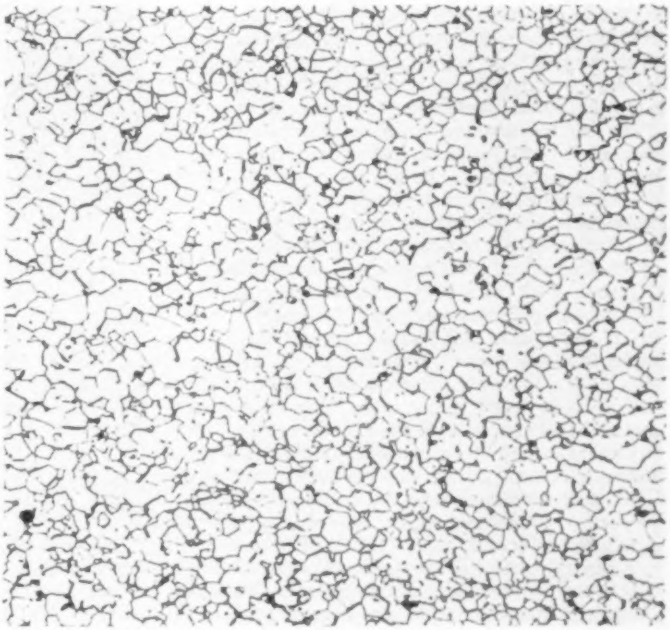


Fig. 2 (× 100).—*Typical microstructures of (a) (left) "top of ingot" and (b) (below) "bottom of ingot" rimming steel*



"gauge length" is used irrespective of sheet thickness), and it is particularly important in the case of cold-worked ductile metals (due to their large ratio of reduction of area to general elongation). Evidently the large variation of the Erichsen values with sheet thickness is due primarily to this effect.

In a material having a relatively poor reduction of area at fracture, the effects of bending under tension may become significant in testing thick sheets. Thus the usual variation of Erichsen value with sheet thickness is reversed in the case of results with a heat-treated Duralumin given in Table I. (The high work-hardening of such a material gives it good tensile stretching properties in relation to its bending performance.)

The foregoing results illustrate reasons why Erichsen tests are not accurately simulative of conditions in stretch-forming a large, thin sheet over a tool of much larger radius. In such an operation localized necking strains can make little contribution to the total stretch and performance in bending is also less important.

(d) Frictional Effects

In stretch-forming tests using an imperfectly lubricated metal tool the applied biaxial stress

Table II—*Rimming Steel Tests*

Chemical analysis (wt per cent)	C	Si	S	P	Mn	Ni	Cu	Sn	Cr	Mo	N
Top of ingot ..	0.040	0.003	0.031	0.013	0.34	0.05	0.11	0.01	tr.	tr.	0.005
Bottom of ingot ..	0.040	0.002	0.021	0.009	0.32	0.05	0.08	0.005	0.004	0.003	0.005

Tensile Tests

Condition	Top of ingot						Bottom of ingot					
	As temper rolled			Aged 6 months			As temper rolled			Aged 6 months		
Direction of test (deg.) ..	0	45	90	0	45	90	0	45	90	0	45	90
Yield point, tons per sq. in.	13.6	14.9	15.7	16.2	17.6	17.9	11.9	13.1	13.0	15.4	16.3	16.1
U.T.S., tons per sq. in. ..	21.0	21.6	21.5	21.1	22.6	22.3	19.7	20.7	20.3	20.8	21.3	20.7
Elongation, per cent on 8 in.	27	29	28	26	24.5	27	33.5	31	35	27.5	26.5	26.5
Elongation, per cent on 2 in.	46	40	41	42	35	39	48	44	48	43	40	42

system is greatly modified by friction. The onset of necking, which leads to failure, and the *location* of the neck, are determined by the combined influences of work-hardening and frictional restraints. With the relatively high friction commonly present in small stretch-forming tests, the regions suffering large thickness strains are narrow (Table I). Thus the result of an Erichsen test may be unaffected by the presence of a localized defect unless it happens to lie within a narrow, predetermined zone of high strain. This is distinct from the case of uniform stretching of a sheet, in which a local defect may determine the position of the onset of necking and cause premature failure. This fact may underlie the relatively unreliable discrimination given by Erichsen tests in a particular examination of rimming steel taken from the top and bottom of a single ingot (Fig. 1). Transverse tensile tests gave a clear indication of the difference in ductility of these two materials, (Table II), which are referred to later in this paper. Microstructures are shown in Fig. 2, and the pattern of macro-segregation in Fig. 3. This latter observation probably provides at least part of the explanation of the wide scatter of Erichsen test results.

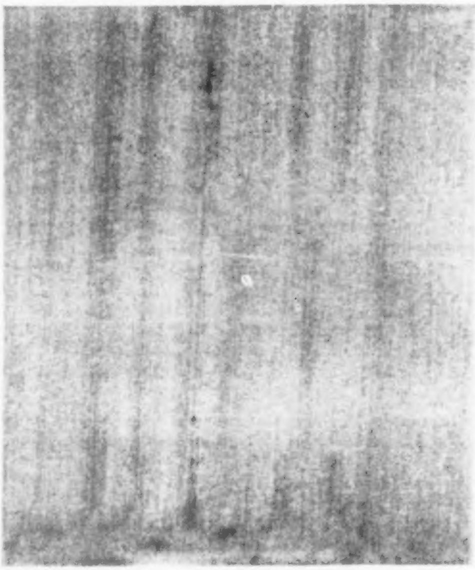


Fig. 3 (× 1.5).—Deeply-etched section of " top of ingot " rimming steel, taken in plane of sheet and in central region

From the point of view of comparing material properties, it can be argued that the hydraulic bulge test has the important merit of indicating the full potential stretch-formability of a metal, since the greatest thinning can be achieved, before plastic instability and failure intervene, when the applied biaxial stress system is unmodified by friction.[1] Only a part of the possible range of stable thinning is explored by a stretch-forming test in which friction is high (or in a uniaxial tensile test). However, a hydraulic bulge test is inconvenient for routine testing and it is not simulative

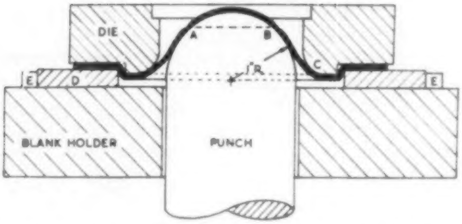


Fig. 4 (above).—Stepped-die method of clamping for stretch forming

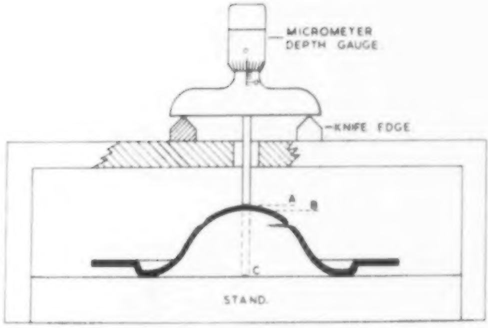


Fig. 5 (right).—Measurement of a stretch-formed specimen

so far as stretch-forming over metal tools is concerned. A method employing metal tools under conditions which allow controlled variations in the frictional restraints is generally to be preferred for a simulative test.

On the basis of the evaluation outlined in the preceding sections it was decided to investigate the performance of a new stretch-forming test, using forming tools appreciably larger than those used in the Erichsen and Olsen tests, in a variable-speed press. The use of a variable-speed press promised two advantages. First, it would allow a wide choice of frictional conditions, since at high rates of forming very low frictional restraints are obtained with liquid lubricants of moderate viscosity: second, speed effects associated with the material itself could be investigated. Since it was envisaged that the test would provide information complementary to that obtained in cup drawing tests, it was also decided, for reasons of economy and convenience, to develop a test which could be carried out on a " Swift " cupping press with a minimum of modification to the latter.

III—Development of the New Stretch-forming Test

The variable-speed " Swift " cupping press (designed and manufactured by Rubery Owen and Co. Ltd.), used in this work has been described previously([2]). High drawing speeds are achieved economically by using a hydro-pneumatic accumulator, and a constant blankholder pressure can be maintained at all available speeds by means of a pneumatic pressure plate.

For simplicity, the punch used in stretch-forming was the same as that used for drawing round-bottomed cups, *i.e.*, a hemispherically-nosed punch of 2 in. (or 50 mm.) diameter.

The main problem in developing a convenient form of the test was to devise an effective method of clamping the blanks, so that stretch-forming was achieved without draw-in of peripheral material, using only the blankholding pressure normally available to the press. Initially the maximum pressure which could be used was 150 lb. per sq. in., giving a holding load of about 3 tons. Clamping rings of 2.4 in. internal and 6 in. external diameters were made to fit in the die housing and over the pressure plate. On the surfaces of these in contact with the blank, sharp serrations were machined in the form of concentric grooves of $\frac{1}{8}$ in. pitch. With this type of clamping a load of 3 tons was found to be insufficient to prevent some draw-in when the thickness of the sheet reached about 0.05 in. (in the case of low-carbon steel).

A more positive method of gripping the blanks was developed using a special die with a single step cut on the working face. The blank was formed into this step by means of a clamping ring of the correct internal diameter, located on the pressure plate. The method is illustrated in Fig. 4. The die was of 2.22 in. internal diameter with a $\frac{3}{8}$-in. profile radius. The diameter of the step was 3.30 in. and its depth $\frac{3}{16}$ in. The clamping ring was of 6 in. external diameter and $\frac{1}{4}$-in. thick. To obtain positive gripping without shearing the test-piece at the step, the internal diameter of the clamping ring was found to be critical to about 0.01 in. The required value depended on sheet thickness and was about 3.50 in. for 0.050-in. thick sheets. This is the biggest disadvantage of this clamping method, which was used for most of the tests discussed in this paper. It has proved reliable but is obviously capable of improvement.

More recently it has been found possible to clamp 0.05-in. material quite successfully, using a flat, serrated die and holding plate, if the holding load is increased to about 4 tons. The formed test-pieces are easily inspected for evidence of draw-in because the sharp serrations imprint extremely fine concentric circles on the flat material surrounding the formed dome.

At high forming speeds it is impracticable to stop the press at the moment of fracture, thus the extent of punch penetration must be predetermined; being selected on the evidence of earlier tests. The punch was stopped at the predetermined point by an adjustable stopping table which was slung

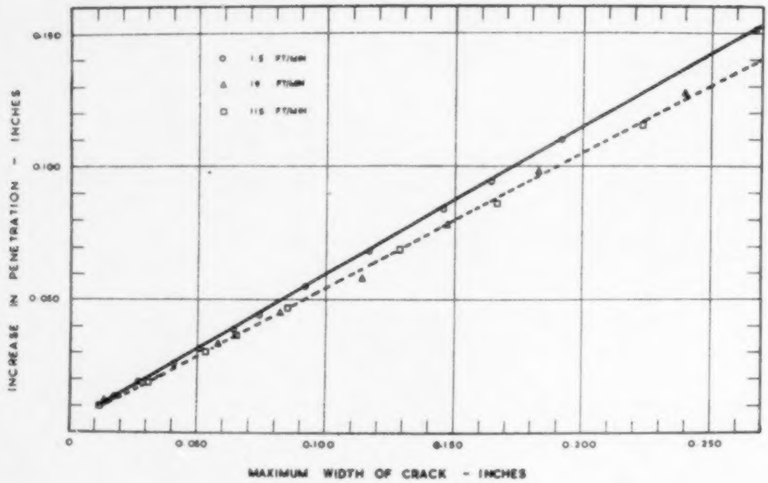


Fig. 6 (left).—Relationship between maximum width of crack and increase in penetration after fracture in stretch-forming test

Figl 7 (below).—Half section of stretch-formed specimen

under the pressure plate housing (Fig. 8). When the main ram hit this the punch was stopped almost instantaneously. The design of the press is such that the main ram pressure was communicated to the crown of the press, through the pressure plate housing, without loading the die. The stopping table consisted essentially of two inclined planes sliding one over the other, so that the effective thickness of the table depended on their relative positions but the external surfaces were always parallel. Adjustment of the table was made by a screw.

The stretch-formability value was defined as the punch penetration which was just sufficient to produce a clear crack. The method of measuring the height of the formed dome is shown in Fig. 5. The thickness of metal at the pole of the dome was subtracted from this measurement to give the stretch-formability value.

At high forming speeds the precise penetration to cause the earliest clear crack could be found experimentally only by successive approximations. This disadvantage has been overcome by making use of the evidence provided by crack widths. It has been found that, for a given material and conditions of forming, there is a linear relationship between punch penetration and the maximum width of the crack, up to quite large values of crack width (Fig. 6). The relationship is dependent, to some extent, on material, forming speed, lubrication and on whether one or two cracks are formed. It was, therefore, redetermined for each different set of conditions used in the tests. However, with known materials, the penetration values can usually be predicted to within 0.05 in. of the true value and variations of the crack width correction value with conditions are then very small.

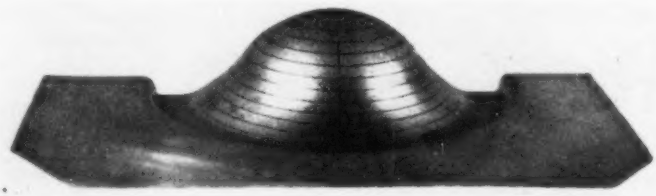
Once the reliability of this technique had been proved all test results were corrected for crack width. Thus the quoted stretch-formability values may be defined as punch penetration to give a crack of zero width. Crack widths were measured on a shadowgraph using a magnification of 50.

This method can also be applied to Erichsen tests ; usually with a marked reduction in the scatter of results.

Test-pieces were normally sheared 5-in. squares with the corners guillotined off accurately on a 6-in. circle, so that they were positioned centrally by locating pins on the pressure plate. A half section of a formed test-piece, with which the stepped die method of gripping was used, is shown in Fig. 7.

Reproducibility of results proved to be very satisfactory. Using material of uniform properties and standardized conditions of tool finish and lubrication, the stretch formability values of batches of 10 specimens were found to be within ± 1 per cent of the mean value.

Little time is spent in specimen preparation for this test, but the time involved in measuring and



correcting the observed penetration values could be excessive for some routine purposes. In this event a very rapid method of testing could be developed, based on judging the relative performances of different samples on crack width measurements alone. For this purpose, punch penetration would be fixed at a value which was known to be sufficient to cause failure in all the material to be inspected. Selection of the most appropriate setting would present little difficulty when large batches of material of nominally the same quality were being examined, and the operations could be carried out by relatively unskilled operators.

IV—Results

The experiments described in this section illustrate the potential value of the new stretch-forming test in relation to small stretch-forming tests, such as the Erichsen, and to deep-drawing tests of the "Swift" type.

(a) Effects Related to the Increased Area of the Test-piece

Table III gives a comparison of results obtained with Al—5 per cent Mg alloy sheets of three widely different thicknesses, all prepared from the same ingot. All the sheets were finally reduced 50 per cent by cold rolling and annealed for 2 hours at 370° C. The variation of penetration at fracture with sheet thickness was much less with the new test than with the Erichsen test. This difference in sensitivity to sheet gauges is ascribed to the much smaller contribution made by necking strains to the total strain in the case of the larger test-piece.

Similar comparisons, made with less ductile materials, have suggested that the new test is also less sensitive to the bending properties of the material than is the Erichsen test.

Apart from the geometric factors just discussed, sample size can be important, particularly with materials having inhomogeneities on a macroscopic scale. Using the large test-piece, discrimination between material taken from the top and bottom sections of the rimming-steel ingots proved to be notably superior to that obtained in Erichsen tests, (Fig. 1). Tests made at medium or high speeds, using a liquid lubricant, appeared particularly useful in this respect; presumably because these conditions reduce friction and give high thickness

TABLE III—*Stretch-forming Tests on Annealed Al-5 per cent Mg Alloy*

Sheet thickness in.	Erichsen test (lubricated)	New stretch-forming test (lubricated. Speed 10 ft. per min.)
	mm.	in.
0.061	10.1	0.785
0.030	8.8	0.744
0.014	7.3	0.713

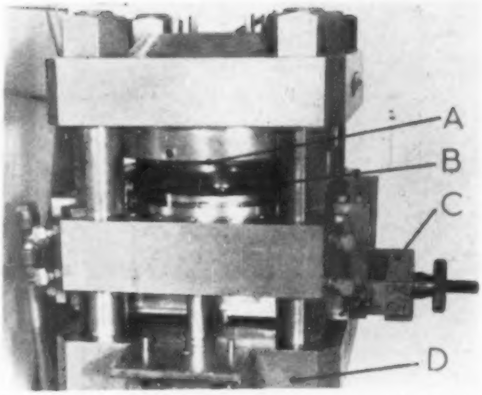


Fig. 8.—Swift cupping press arranged for stretch forming with serrated plate clamping. A, die with serrated face. B, serrated plate on pressure plate. C, adjustable stopping table. D, main cylinder (operating hemispherically nosed punch)

strains over a larger area of the specimen (Figs. 11 and 12). Penetration values (in inches) obtained on temper-rolled sheets approximately 0.04 in. thick, taken from five different ingots, were as follows :—

Ingot No.	1	2	3	4	5
Top of ingot	0.973	0.925	0.973	0.972	0.958
Bottom of ingot	0.986	0.966	0.989	0.979	1.002

These tests were made at approximately 19 ft. per min. using an E.P. lubricant (Esso T.S.D. 996). The material from ingot No. 5, which shows a large difference, is that referred to previously in Table II and Figs. 1 to 3. In this case the quoted results are averages taken from 10 samples. Individual penetration values lay within ±0.018 in. of the mean value in the case of top-of-ingot material, and within ±0.012 in. of the mean with bottom-of-ingot material.

(b) Extension of the Scope of the Test by Changing the Forming Speed

Significant speed effects can arise in stretch-forming due to changes in plastic behaviour of the metal with strain rate and to changes in lubrication with tool speed. Interactions of these effects may lead to complex behaviour which cannot be predicted from slow tests.

For example, Fig. 10 shows an unexpected change, with forming speed, in the relative merits of a deep-drawing quality rimming steel on the one hand, and two stabilized steels on the other. The rimming steel sheets were "bottom of ingot" material of a quality similar to that described in Table II and Figs. 1 to 3.

Details of the two stabilized steels, which were processed to give "pancake" and "equiaxed" grain structures respectively, are given in Table IV

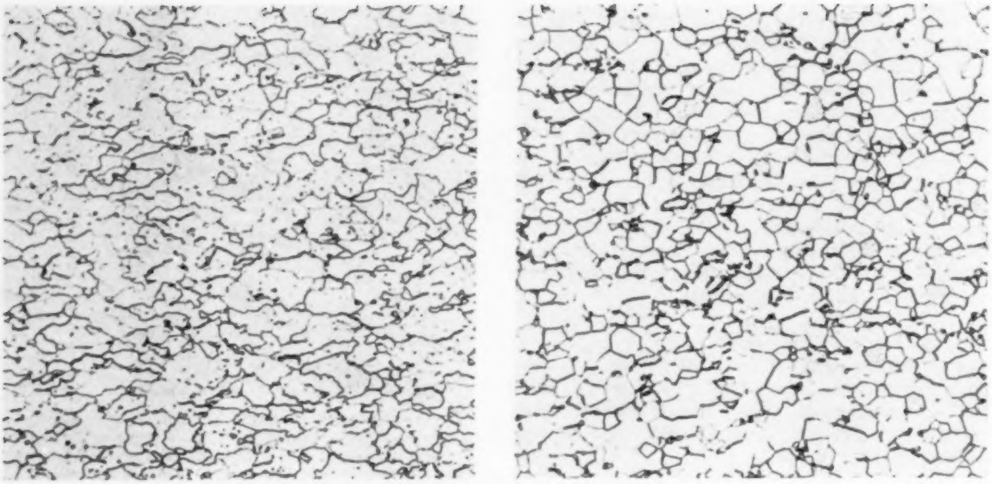


Fig. 9 (× 100).—Microstructures of (a) (left) "pancake" and (b) (right) "equiaxed" grained stabilized steels. Longitudinal cross-sections

and Fig. 9. The lubricant used was an E.P. oil containing 90 per cent mineral oil and 10 per cent chlorinated wax and having Redwood I viscosity of 86 sec. at 93° C. and a viscosity Index of 67.5 (Esso T.S.D. 996). This same oil was used for all the forming and drawing tests made with a liquid lubricant which are reported in this paper.

At punch speeds of 1.5 and 19 ft. per min. performance of the rimming steel was similar (or even superior in the freshly temper-rolled condition), to that of the stabilized steel, but at the high speed of 115 ft. per min. the rimming steel was less good, particularly in the aged condition. To interpret these results, the differing characteristics of the speed effects associated with changes in the plastic behaviour and changes in lubrication must be considered.

With liquid lubricants friction is generally reduced by increasing the forming speed because a thicker film of lubricant can be maintained at higher tool speeds(2) The effects of this on the distribution of thickness strains in stretch-forming tests is illustrated in Figs. 11 and 12. The much larger strains which have developed in the polar regions of the hemispheres at the high speeds are due primarily to a relaxation of the frictional restraints

TABLE IV

Stabilized-Steel Tests

Chemical analysis, wt, per cent	C	Si	Mn	S	P	Ni	Cu	Sn	Total Al
"Pancake" grained steel	0.065	0.006	0.47	0.022	0.01	0.06	0.07	0.02	0.06
"Equiaxed" grained steel	0.065	0.006	0.47	0.023	0.01	0.07	0.08	0.02	0.10

Tensile Tests (Temper-rolled Condition)

Material	"Pancake"			"Equiaxed"		
Direction (w.r.t. rolling direction) (deg.)	0	45	90	0	45	90
0.1 per cent proof stress, tons per sq. in.	10.1	11.5	10.9	11.7	12.4	12.2
U.T.S., tons per sq. in.	19.8	20.6	19.8	19.6	20.0	19.9
Elongation, per cent on 8 in.	34	32	31	36	32	29
Elongation, per cent on 2 in.	54	46	45	45	44	37

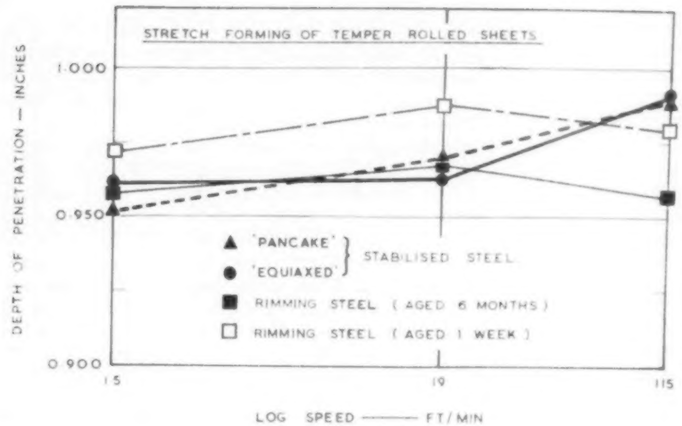


Fig. 10 (left).—Effect of tool speed on penetration at fracture in stretch-forming temper-rolled deep-drawing-quality steel sheets, 0.038 in. thick, using an oil lubricant.

Fig. 11 (below, left).—Effect of forming speed on distribution of thickness strains in stretch-forming (to fracture) temper-rolled stabilized steel, using an oil lubricant. Penetration values are given in Fig. 10

Fig. 12 (below right).—Effect of forming speed on distribution of thickness strains in stretch-forming a temper-rolled rimming steel, using an oil lubricant

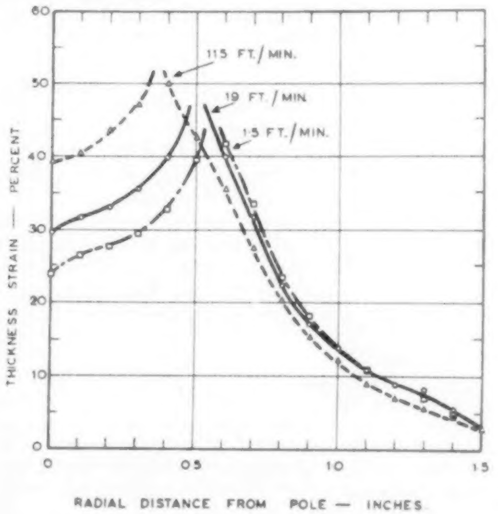
which tend to limit deformation in the material making early contact with the tool.*

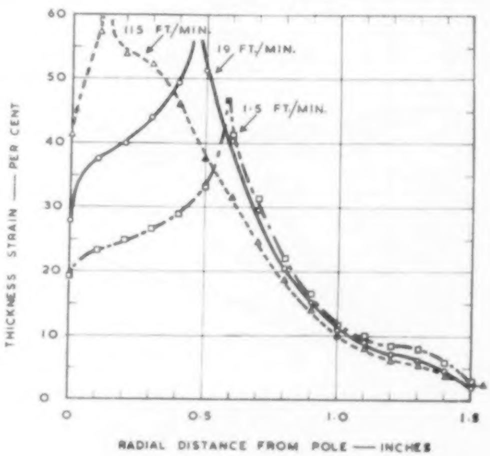
Most metals, when stretch formed using a liquid lubricant, show improved formability with increased punch speed because the lubrication effect is generally dominant. In this respect the results for the stabilized steels given in Fig. 10 are typical.

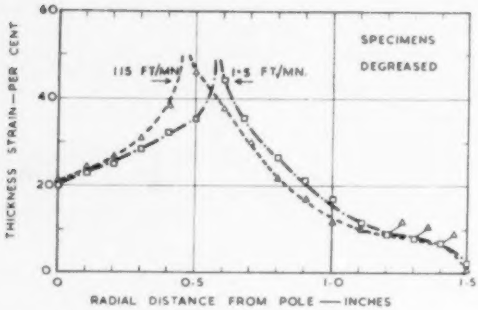
The effects of strain rate on the plastic behaviour of the metal can be examined in stretch-forming by using a solid lubricant, such as graphite, which is insensitive to speed. In this way it is easy to demonstrate that a change in forming speed in the range 1 to 100 ft. a minute has little direct influence on the performance of a metal such as brass([2]).

* The value of results obtained under conditions of very low friction has been indicated in Section 2. Using a moderately viscous oil lubricant at very high forming speeds enables conditions present in a hydraulic bulge test to be approached, while retaining the convenience of metal tools.

Low-carbon steels, on the other hand, show speed effects in the absence of liquid lubrication (Fig. 13). Increasing the punch speed gives a neck nearer the pole of the hemisphere and a lower punch penetration. These effects are due to the relatively high strain-rate sensitivity of the plastic behaviour of steel. Increased strain rate causes a marked increase in the yield stress and an appreciably smaller increase in the flow stress at high plastic strains (Fig. 14). In stretch-forming, the yield is initiated in the central region of the blank and spreads outwards towards the periphery as the central region continues to strain and to work harden. At high forming speeds, because of the modified stress-strain relationship (which is, in effect, one of reduced work hardening), higher strains will be required in the more heavily deformed central regions in order to support the stresses required for yield in the peripheral regions. For this reason necking strains are reached in the central region







before general thinning has progressed so far as it does at lower speeds (Figs. 12 and 13). In this way increases in forming speed tend to reduce the stretch formability of low carbon steels if frictional conditions are maintained constant.

With liquid lubricants, on the other hand, improvement in lubrication with increased speed acts to improve stretch formability. The authors believe that the unexpected behavior of the rimming steel (Fig. 10), which tends to show a maximum formability at a speed in the region of 19 ft. per min. under the particular conditions of lubrication and tool form, is a consequence of the combination of these two influences. If this interpretation is

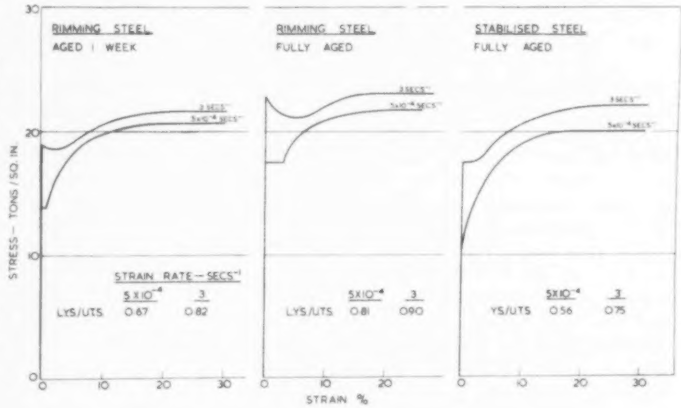
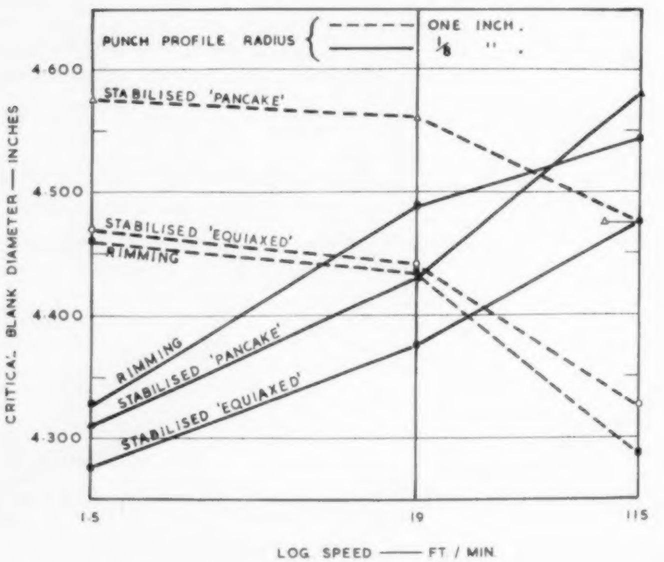


Fig. 13 (above).—Effect of forming speed on distribution of thickness strains in stretch-forming an unlubricated, temper-rolled rimming steel. Punch penetrations at fracture; 0.98 in. at 1.5 ft. per min., and 0.92 in. at 115 ft. per min.

Fig. 14 (right).—Stress-strain curves, at high and low strain rates, of a temper-rolled rimming steel (aged 1 week and more than 6 months) and of temper-rolled "pancake" stabilized steel (aged more than 6 months)



correct, the absence of a fall in the stretch formability of the stabilized steels at 115 ft. per min. must be due to a difference in the effects of strain rate on the stress-strain relationships. Possible support for this conclusion is given by the uniaxial tensile tests illustrated in Fig. 14. These are typical test results, made at strain rates of 5 by 10^{-4} and 3 sec.$^{-1}$, on the stabilized steels and the two conditions of the rimming steel. They show that the two conditions which gave a decrease in formability

Fig. 15 (left).—Effects of drawing speed and tool form on drawability of three temper-rolled deep-drawing-quality steels. Lubricant Esso T.S.D. 996

with increased speed, (the lightly and fully aged rimming steel tested at the highest speed) were those having the highest ratios of lower yield stress to ultimate tensile strength.

The pattern of the differences in the thickness strains, observed in rimming and stabilized steel samples formed at 115 ft. per min., (Figs. 11 and 12) is also consistent with an explanation in terms of the effects of strain rate on the balance of the plastic strains which develop during stretching.

(c) The Relation of Results of Stretch-Forming and Deep-Drawing Tests

In the previous two sections examples of the increased scope provided by a large stretch-forming test, made on a variable speed press, have been considered in relation to the kind of information given by existing tests of the Erichsen type. Examination of the relation of the new test to cup-drawing tests is no less important, since pressing operations which combine stretch-forming and deep drawing often present the most difficult problems in the prediction of material performance.

The conventional criteria of performance used in these two types of test lead to important differences in their assessments. This is easily illustrated by referring again to the speed effects observed with a liquid lubricant. Fig. 15 shows the variation of the critical blank diameter with punch speed, observed in deep drawing the same steels with the same lubricant as was used in the stretch-forming tests referred to in Fig. 10. With a flat-nosed punch having a $\frac{1}{4}$-in. profile radius, drawability improved with drawing speed, but with the hemispherically nosed punch (the same tool as was used for stretch forming), drawability decreased markedly with increased speed. The sources of speed effects in deep drawing have been analyzed in an earlier paper([2]) and need not be discussed in detail here. In the present case the effects are due primarily to improvement in lubrication with drawing speed. Improved die-side lubrication tends to increase drawability by reducing the drawing load, but improved punch-side lubrication tends to reduce drawability by decreasing the load which can be supported by the material over the punch head. While, with the flat-nosed punch, the die-side lubrication effects are more important, results with the hemispherically nosed punch are dominated by the punch-side lubrication effects.

In the stretch-forming test, as was seen earlier, improved lubrication on the punch generally improves performance (*e.g.*, the results for stabilized steels in Fig. 10). Thus, using a hemispherical punch, speed effects associated with changes in friction are rated quite differently in the two types of test, despite the fact that the systems of straining and mode of failure, within the stretch formed zones, are essentially similar. This illustrates the complementary nature of the criteria of performance used in the two tests. Taking a very simplified view, it might be said that in stretch forming failure occurs at a critical strain, but in a deep-drawing test it occurs at a critical stress.

The results in Figs. 10 and 15 provide a second, more subtle, example of the value of combining the information given by stretch-forming and deep-drawing tests.

The two stabilized steels selected for examination were of similar composition and had similar strengths and general elongations in tensile tests (Table IV). The only marked difference immediately apparent was in grain structure (Fig. 9), consequent on the difference in cooling treatments after hot rolling. Performances of these two materials in the stretch-forming tests were almost identical, but in deep drawing the "pancake"-grained material was markedly superior to the " equiaxed " condition, particularly with the hemispherical punch and at high speeds. This superior drawing performance of " pancake "-grained material is well known and is believed to be correlated with differences in plastic anisotropy([3], [4]).

Ordinary tensile tests give information about directional properties in the plane of the sheet only, but some evidence of plastic behaviour in the important thickness direction is obtained by measuring the " R " ratios. " R " is the ratio of the plastic strains in the width and the thickness directions, observed in the tensile test-piece at a convenient value of extension within the uniform elongation range. Grain shape may be involved, but observed variations of R in sheet steels are probably chiefly dependent on preferred crystallographic orientations; the active slip planes in sheets of high R ratio being oriented to promote plastic flow which reduces specimen width rather than thickness. Burns and Heyer([3]) showed that a strong $(\bar{1}11)$ [110] texture would be expected to give R ratios appreciably greater than unity for all directions of testing in the plane of the sheet. They showed that " pancake "-grained material had an appreciably stronger $(\bar{1}11)$ [110] component

TABLE V—*Plastic Anisotropy of Temper Rolled Steel Sheets*

Material		Rimming steel	Stabilized steels: " Pancake "	Stabilized steels: " Equiaxed "
		in.	in.	in.
Amplitude of ears in cups drawn from 4.35-in. blanks		0.21	0.30	0.18
	Angle to R.D. (deg.			
" *R* " *ratios*	0	1.16	1.54	1.11
(average of 12	45	0.97	0.98	1.02
measurements)	90	1.45	1.67	1.42

Table VI—*Load Measurements for Stretch-Forming and Deep-Drawing Stabilized Steel Using a Hemispherical Punch at* 1.5 *ft. per min.*

(1) *Stretch-Formed to a Penetration of* 0.87 *in. Without Fracture*

Material	Specimen numbers	Individual pen deflections (in.)	Individual Sheet thicknesses (10^{-3} in.)	*Mean stretch forming load
" Pancake "	P1—3	3.20, 3.27, 3.27	38.0, 38.2, 37.8	4.52 tons
" Equiaxed "	E1—3	3.10, 3.12, 3.10	38.0, 38.2, 37.8	4.33 tons

* Calculated on mean original sheet thickness of 0.0380 in.

(2) *Deep-Drawn* (*Without Fracture*). *Blank Diameter* 4.40 *in.*

Material	Specimen numbers	Individual pen deflections (in.)	Individual Sheet thicknesses (10^{-3} in.)	† Mean drawing load	† Mean minimum thickness at base neck (10^{-3} in.)
" Pancake "	P4—10	4.77, 4.69, 4.68, 4.88, 4.87, 4.78, 4.86	38.4, 37.0, 37.1, 38.1, 37.9, 37.4, 38.3	6.70 tons	28.8
" Equiaxed "	E4—8	4.62, 4.74, 4.66, 4.68, 4.70	37.8, 37.9, 37.7, 37.5, 37.6	6.54 tons	25.3

† Calculated on mean original sheet thickness of 0.0377 in.

of the texture than either an " equiaxed " stabilized steel or sub-critically annealed rimming steel. Pole figures have not been determined for the materials used in the present work, but the R ratios were generally similar to those observed by Burns and Heyer, also the relative severities of earing seen in cupping tests were in qualitative agreement with the intensities of the preferred orientations which they observed (Table V).

The general conclusion reached in earlier investigations is that the better drawing performance of " pancake "-grained materials of high R ratio, must be related to their greater resistance to thinning during tensile straining. This observation is insufficient to give a clear picture of behaviour in the complex conditions of biaxial stretching and deep drawing. In fact, the stretch-forming results in Fig. 10 show that strains to fracture in conditions of biaxial stretching were not significantly different in the two stabilized steels. (Thus, in simple stretch forming, the " pancake " material may provide no advantage).

This observation shows that the improved drawability with " pancake " material must be due to its having a *lower* value of the ratio, maximum drawing load/load required to fracture the base, than that of the corresponding ratio for the " equiaxed " material when drawn under the same conditions. Table VI gives results of accurate load measurements, made on blanks of strictly comparable thickness, in stretch forming and drawing with the hemispherical punch. These show that the differences in drawing loads with " pancake " and " equiaxed " materials were quite small, but, if anything, tended to favour the latter. However, the load required to thin the base to a predetermined amount (stretch-forming experiment) was more appreciably greater with the " pancake " material. The difference in stretching load at a penetration of 0.87 in., using a low speed, was only about 4 per cent but there is little doubt that, at higher strains and higher speeds, this difference in strength will become more considerable. Certainly there was a bigger difference in the fracture loads observed in deep drawing large blanks. Also, when blanks of the same size were drawn in " pancake " and "equiaxed"-materials, the bases of the cups drawn from " pancake "-grained material were left appreciably thicker (Table VI). Evidently the superior drawability of " pancake " material is not related to any simple change in ductility, rather the anisotropy of plastic strength is such as to increase resistance to thinning in biaxial stretching without correspondingly increasing resistance to radial drawing.

V—Conclusions

(*a*) The value of the stretch-forming test as a simulative test has been discussed and results have been presented to illustrate how the accuracy and scope of the test can be improved by using a hemispherical forming tool of 2 in. (or 5 cm.) diameter in a variable-speed press.

(*b*) In some respects the information given by stretch-forming tests is complementary to that derived from deep-drawing tests, and there is much to recommend applying both types of test in any comprehensive examination of sheet-metal

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METAL SPRAYING

Report of Papers Presented at The Annual Assembly of the INTERNATIONAL INSTITUTE OF WELDING

DURING the recent annual assembly of the International Institute of Welding a Colloquium was held on Metal Spraying under the aegis of the Institute's Commission I.

In the " Memorandum " relating to the organization of the colloquia of the Assembly 1960, *the International Institute of Welding stated that they should be devoted to precise problems covering a limited field that could be investigated in one meeting.*

It appeared that the Commission when choosing flame-spraying somewhat under-estimated the extent of the subject and the variety of problems which might arise.

The interest in flame-spraying was largely shown by the fact that 13 *papers were presented and that a fourteenth paper was announced, but could not be presented in time.*

These papers covered a very wide field, and were classified as follows:

1. Physics of Flame-spraying
- (*a*) *H. D. Steffens: New Considerations about Metal-Spraying with Gas or Arc-Gun (French).*

2. Preparation
- (*a*) *N. Aubry: Use of Plastic Varnish as Bonding Base (French).*

3. Sprayed Materials and Properties of the Layer.
- (*a*) *M. A. Levinstein: Recent advances in Arc-Plasma Metallizing (English).*
- (*b*) *D. G. Moore: Flame-spraying of Aluminium Oxide (English).*
- (*c*) *N. N. Ault and W. M. Wheildon: Metal Oxide Flame-spraying for High-temperature and other Applications (English).*
- (*d*) *T. P. Hoar: Metal Spraying in the Protection of Iron and Steel (English).*

4. Special Problems in Application
- (*a*) *N. S. Miller: High-temperature Corrosion Protection with Spray-Metallized Coatings (English).*
- (*b*) *Dr. J. Friedli: Zinc-Spraying used as Corrosion Protection in the Hydro-electric Industry (French).*
- (*c*) *A. R. Old: The Economics of Metal Spraying as applied to Deep-Sea Trawlers and other Small Craft (English).*

5. Economies
- (*a*) *W. E. Ballard: Some Thoughts on the Economic Aspect of Metal Spraying (English).*

6. Normalization
- (*a*) *Z. Kowalski: Standards, Recommendations and Specifications for Metal-spraying (French).*

7. Teaching
- (*a*) *A. Hedde and L. Zambeaux: Teaching Problems about Metal-spraying (French).*
- (*b*) *Dr. C. G. Keel: Conception and Organization of Metal-spraying course of lectures in Switzerland (French).*

The following general review of the papers was given by Prof. G. A. Herpol, the reporting member of the Commission.

A FUNDAMENTAL investigation into the physico-chemical basis of bonding was presented by H. D. Steffens in his paper *New Considerations about Metal Spraying with Gas or Arc-Gun.*

According to present knowledge of the physics of surface condition, Mr. Steffens says that there are, at the surface of pure chemical elements, forces available for absorbing atoms or molecules provided they are not too distant, since the attraction field of these forces is proportional to the atom diameter. This takes place through electron exchange, the available forces depending on the electron-emitting power, which is largely influenced by the surface purity, whether absorption is already saturated (*e.g.* through oxidation) or whether the parent surface is composed of mixed crystals in which absorption forces are partially neutralized.

This method of bonding is not the only possibility, but it works for metals with great reciprocal affinity and with non-saturated electron nets. Macro- or microscopical roughness of the basic surface may have little influence on the absolute value of contact surfaces, but it may be important in the deformation of the basic surface by the impact of sprayed metal droplets, *i.e.*, the flattening of points of roughness. This creates a semi-liquid state and bonding is, in that case, very much like pressure welding. It would seem that bonding is

obtained through this mechanism, by all methods of application.

Comparing the conclusions of experiments in the field of powder metallurgy, these tend to show that thermic activation, *i.e.*, that resulting from rising temperature, is not possible in the flame-spraying and cold-welding fields, which in turn indicate that to get good bonding, temperature must be minimized.

In conclusion, Mr. Steffens states that heat increases the bonding initiated by mechanical activation.

The author presents the scheme of bonding as follows : the projected particle, due to its kinetic energy, flattens the points of roughness, creating diffusion surfaces, the extent of which depend on many factors, namely the nature of the metals, mass, density and temperature of particles, and the physical state (solid or liquid) of the oxide layer covering these particles. This makes available numerous bonding points by diffusion in which the oxides play their part.

In this field many differences may be noticed between metallization with a reducing flame or with an oxidizing arc. Further widening of this set of points depends on various phenomena, whether the necessary energy is supplied by the enthalpy of the particle, erratic atomic forces or recrystallization. Finally, the important temperature gradient in the bonding zone and inside the layer causes a fine-grained structure, as in castings and when crystallization progresses rapidly towards the inside of the particles it develops residual stresses which must be counter-balanced by cohesion forces in the layer and bonding forces at the surface.

Macroscopic roughness of the surface is favourable since the residual stresses are chiefly shear stresses along the surface. As for the bonding, perpendicularly to the surface, it plays only an accessory part.

Mr. Steffens stresses the fact that this qualitative presentation of a very complex phenomenon cannot yet be followed by a quantitative presentation, although certain facts are already known in this field. Here is an open field for investigation, which will have to be explored systematically if it is intended to further knowledge of the metallization process.

* * *

N. Aubry in his paper *Use of a Plastic Varnish as a Bonding Base* contributes further information to the preparation of surfaces before metallizing. Noticing that mechanical preparation is very expensive, he made some investigations in the use of a varnish made of nylon dissolved in phenol.

Application of this varnish is made after simple etching. This coat reduces to some extent the bonding force which might be obtained on a sand-blasted surface, but gives sufficient bonding for corrosion protection using zinc metallization. Mr. Aubry does not explain the action of his varnish, but states that the coat had been torn by particles clinging to the parent metal and had shrunk between the bonding points. Most probably the better corrosive protection offered by nylon is due to the fact that the bonding net enhances galvanic protection.

Mr. Aubry draws special attention to the low cost of the process.

* * *

The astronautical era has instigated considerable scientific interest in producing materials able to withstand very high temperatures. This has led to the resumption of the study of plasma-metallization, which dates back to the beginning of this century.

Some papers presented are therefore devoted entirely to this subject. It has been the ultimate goal of all metallizers to obtain coatings capable of withstanding temperature, corrosion, and at the same time being themselves thermal insulators.

M. A. Levinstein's paper *Recent Advances in Plasma Arc Metallization* partially realizes this old dream in the form of an arc-gun in which a concentrated arc is the source of heat at the highest possible temperature. The arc can be obtained from any type of welding apparatus and a high-frequency spark is superimposed on it to ignite and stabilize the arc. If the sprayed material is a metal wire, the wire may be used as an electrode, the nozzle of the gun being made with a refractory material. If the sprayed material is a powder, an adjustable electrode is used. Polarization seems to be of no importance.

The carrying gas constituting the plasma may be argon or nitrogen with a 10 per cent addition of hydrogen. The highest temperatures are reached with helium, the highest enthalpies with hydrogen.

A study has been made to determine the properties of layers of materials with a fusion point above 2,482° C. (4,500° F.). Materials used were tungsten, molybdenum, tantalum carbide, hafnium carbide, oxides of cerium, zirconium and hafnium.

An aluminium tube was chosen as the support since the coating could be taken off without corrosion and cooling could be carried out from the inside. Mr. Levinstein described how test-pieces were made and heat treated.

From these tests it appeared that tungsten and molybdenum projected with argon, absorb very little nitrogen but take a good deal of oxygen. These absorptions are greater in the case of a sprayed powder than in the case of a wire.

Mr. Levinstein assumes that absorption takes place when the sprayed material is settled. The deposit of the metals quoted above has an average density 2 per cent higher if the sprayed metal is a wire, but the density can be raised from 2 to 2.5 per cent for the wire deposits and from 1.5 to 3 per

cent for the powder deposit, by heating at 1,982° C. (3,600° F.).

Hardness of deposits is higher for wire but on average is lower than that of the metal itself, probably because of porosity. The structure of these deposits is distinctly lamellar and formed by wide lamellae separated by intergranular structures. A heat treatment at 1,982° C. (3,600° F.) produces recrystallization: the lamellar structure is retained with tungsten, but disappears with molybdenum.

The lamellar structure is more uniform and less marked for powder metal but, in this case, the two metals behave very differently when heat treated: tungsten recrystallizes completely in fine grains, while molybdenum shows very coarse grains.

Deposits, even after annealing, are brittle and all specimens broke with brittle fracture, with the exception of molybdenum powder which reached 23 per cent elongation before breaking.

It should be noted that at 1,093° C. (2,000° F.) molybdenum wire gives 50 per cent more resistance than molybdenum powder, but the wire loses its ductility.

The spraying of carbides (Ta C and Hf C) shows that deposits are composed of several phases indicating that carbides undergo transformations during metallization.

It seems that the transformation is caused by carbide dissociation, with carbon loss, followed by oxidation, and even nitriding of the liberated metals. Indeed, while tantalum carbide contains 6.23 per cent carbon, the deposit bears only 1.12 per cent but shows 0.326 per cent nitrogen and 1.96 per cent. oxygen. With hafnium, the existence of a complex Hf (CN) is probable.

Substituting nitrogen for argon as the carrying gas, both mixed with 10 per cent hydrogen, deposits obtained are quite different, but the previously mentioned phenomena still appear.

Mr. Levinstein had only a few results related to oxide deposits: it seems that neither structure, density nor hardness are much changed.

* * *

The paper by D. C. Moore, *Flame Spraying of Aluminium Oxide*, presents information gathered from a series of tests initiated by the National Bureau of Standards. To get the aluminium oxide deposit, oxyacetylene guns were used, with either wire or powder. The average diameter of the projected particles was, respectively 6.4 μ and 13.4 μ.

By cinematographic means, it has been shown that a gun fed with a 3.2 mm. (⅛ in.) wire at the rate of 16.5 cm. per min. (6½ in. per min.) sends bundles of particles, each bundle being projected during 1/1,000 of a second, the interval between two bundles being of the magnitude of 6/1,000 of a second. The speed is measured by three methods, cine camera, streak camera and revolving disc.

For the wire gun, it is a maximum at about 50 mm. from the nozzle and reaches 180 m. per sec., falling rapidly further on. The powder gun gives lower speeds, the maximum being about 45 m. per sec.

By projecting particles travelling at 1 m. per sec. on to a series of microscope glasses, by means of a gun, the formation and analysis of the deposits have shown that at a distance of about 50 mm., from the nozzle the particle is composed of an external liquid layer containing solid alumina. At about 100 mm. the particle is entirely molten, but it cools rapidly and at 150 mm. from the nozzle it has a solid wall, containing some liquid.

At 350 mm. from the nozzle the particle no longer clings to the glass, which agrees with theoretical calculations which show that a liquid particle of 10 μ travelling at a speed of 45 m. per sec. would solidify completely after 300 mm. in an atmosphere 200° C. colder than the particle itself. It may be concluded that particles emitted by a wire gun, being much more rapid than those of a powder gun, will remain liquid at a greater distance from the nozzle.

Mr. Moore tried to establish cooling gradients through calculus. This, without absolute value, shows the important part played by the basis material on this cooling gradient which is very important in the beginning, and depends essentially on heat conductivity and the thermal capacity of the material.

Measuring the apparent shear resistance at the bonding surface, Mr. Moore shows that to reach a good shear resistance it is necessary to have a rough surface, either metallic or covered with a well clinging layer of oxide. Though all these tests do not yet explain the phenomenon, it appears that mechanical bonding is the chief factor.

The author draws the conclusion that much research work has still to be done before it is possible to understand the phenomenon of the particles' impact.

Nevertheless, oxide spraying and particularly aluminium oxide spraying, is being used industrially.

* * *

N. N. Ault and W. M. Wheildon in their paper *Flame Spraying of Metallic Oxides for High-temperature and Other Applications* describe the processes used for spraying oxides. All these processes make use of a heat source to melt the oxide and of a compressed gas to project the particles. The heat source is either combustion at constant pressure, an explosive combustion or an electric arc. Besides an oxyacetylene flame, other combustible gases were used, for instance, cyanogen, or powders, like aluminium powder. The last two being dangerous, gave a very high temperature, especially in explosive combustion since the temperature of the

explosive wave can reach 2,760° C. (5,000° F.).

The electric arc in the carrying gas rises to 16,650° C. (30,000° F.) with certain monoatomic gases.

The coating material is in the form of a rod or a powder. Wire seems to have advantages over powder, for which the controlling factors, nozzles orifices, pressure and pulsation of gas, condition of powder, etc., have to be maintained between narrow limits.

The authors confirm the conclusions of Mr. Moore, that bonding of refractory coatings is merely mechanical and requires a controlled surface roughness, such as that obtained by sand-blasting or by the deposit of an underlaying metallized layer. Materials able to form refractory coatings are numerous: oxides, carbides, borides, nitrites, chlorides, etc. Every material susceptible to melting in a stable liquid form may be projected, even if sometimes it decomposes in the flame. Generally, preference is given to oxides ($Si\ O_2$—TiO_2—$Zr\ O_2$—$Cr\ O_2$) or complex oxides such as wollastonite, ilmenite, forstenite, mullite, etc.

As a rule, the deposits are somewhat porous for it is practically impossible to obtain a completely molten coating: too rapid coolings are unavoidable causing partial fusion. The porosity is less than 10 per cent: it makes the coating able to endure more elongation before failure than could be expected.

The structure of deposits being generally laminar, their strength fluctuates according to the direction of measurement: this amounts to 70 kg. per sq. mm. (100,000 lb. per sq. in.) for chromium oxide, for example.

Thermal conductivity of the deposits is very low and so they can take in their mass important temperature drops. The deposit can be melted without melting the substrate. Conductivity may be calculated starting from that of the material, taking into account the porosity and the oriented structure. Because of this, the deposits withstand high thermal shocks. The resistance against thermal shocks is improved by a thermal expansion coefficient slightly lower than the basic one, by a good roughness of the substrate and by application of a convenient undercoat.

Deposit properties are different from those of the workpiece because of changes in structure, dissociation, oxidation or reduction. Examining the conditions to be fulfilled by sprayed materials according to what is expected from the coating, Ault and Wheildon note that, although it is possible to make coatings that do not melt at 2,204° C. (4,000° F.), limitations are still imposed on refractory coatings.

Investigation could be made in several fields: sealing, thermal expansion, thickness and deposition rate.

Dr. T. P. Hoar in his paper *Metallization against Corrosion of Iron and Steel*, exposes briefly the methods in use for obtaining those coatings. He confirms some peculiarities of the phenomenon noted by Mr. Steffens, especially those concerning oxide content and porosity. He shows that, due to the cathodic protection they provide at the beginning and, later, to the formation of oxy-carbonates or hydroxycarbonates, porosity is not troublesome, on the contrary it offers an excellent bonding base for sealing.

Generally, zinc gives better protection in marine atmospheres while aluminium prevails in industrial atmospheres. Zn-Al alloys too give very good results in various atmospheres, but the addition of Mg reduces their efficiency. The best proportion is 60 per cent aluminium.

As for preparation, Dr. Hoar thinks that the only important point is to obtain a chemically-clean surface, roughness playing a secondary part in bonding.

He recommends that metallized surfaces be painted since the combination of metallization with paint gives probably the best protection which can be contrived.

* * *

N. S. Miller in his paper *High Temperature Corrosion Protection with Spray-Metallized Coatings*, looks, in the light of known metallization techniques, for the best way for protecting basis metals.

Below 510° C. (950° F.) corrosion of iron and steel can be reduced by aluminizing. A thin layer of aluminium can prevent corrosion of iron, if the surface to be sprayed has been conveniently cleansed and sand-blasted and that metallization is done immediately after. It is advisable, in order to avoid penetration of moisture through porosity, to proceed to sealing with silica gel.

Above 538° C. (1,000° F.) and up to 1,093° C. (2,000° F.) some metals, like iron and molybdenum, are quickly oxidized: a good protection can be obtained with two types of coating:

(1) metals and alloys forming adherent oxides.

(2) materials withstanding oxidation at high temperatures.

To the first group belong aluminium, copper and alloys Al—Ni—Cr, Ni—Cr—Bo and Al—Cd. These coatings have to be heat-treated after application, in order to obtain, superficially, the formation of the alloy, and special precautions must be taken in the preparation of the surface and sealing after metallization. Temperature and atmosphere for heat-treating must be adequate. None of these alloys are very convenient: *e.g.*, aluminium is not good above 871° C. (1,600° F.) and nickel does not withstand sulphur, while aluminium withstands it perfectly. So it appears logical to make compound coatings for temperatures between 871° C. (1,600° F.) and 982° C. (1,800° F.):

an underlayer of 0.33 to 0.43 mm. (0.13 to 0.17 in.) of Ni—Cr and then a layer of Al of 0.076 to 0.127 mm. (0.003 in. to 0.005 in.).

Over 1,098° C. (2,000° F.) up to 2,482° C. (4,500° F.) inert coatings must be used. One is limited, therefore, to ceramic materials and noble metals though the latter are reserved for special uses. Ceramics are of the metallic oxide type (oxides of zirconium, aluminium chrome, etc.).

Mr. Miller confirms all the characteristics mentioned by Ault, Levinstein and Wheildon, but points out the possibility of using zirconium silicate or borides. All these products may be sprayed on to numerous base metals. He recommends intermediate metallized layers before spraying with the ceramic product : nickel-chrome alloy, copper and molybdenum were used with success, especially on cylindrical surfaces. These ceramic coatings may be sealed, but sintering does not seem to help.

Mr. Miller concludes with a view of the treatment for the space craft of the future : a basis metal withstanding high temperatures, an undercoat of refractory metal to give resistance and conductivity, a ceramic layer giving thermal insulation and resistance against oxidation and, finally, an outer film of nylon sprayed on phenolic, giving a smooth exterior surface.

* * *

In the field of zinc spraying, Dr. J. Friedli, in his paper *Zinc Spraying for Protection against Hydro-electric Corrosion*, is not of the same opinion as Dr. Hoar about preparation. He thinks cleanliness not sufficient and roughness indispensable. He advises blasting with quartz or carborundum. In the contemplated application, Dr. Friedli suggests that zinc layers must be thick, about 1,000 gm. per sq. m., for zinc does not withstand fresh water too well, cathodic protection being paralyzed in this particular case.

For these coatings, thickness and adherence are very important ; to check the first one an electromagnetic method is recommended, and for the latter a chisel test may be used. Dr. Friedli also thinks that subsequent painting is necessary to insure good protection and recommends various layers of varnish, containing chiefly bitumen, which are easily repaired when damaged.

* * *

In a field where corrosion is particularly important, A. R. Old in his paper *The Economics of Metal Spraying as applied to Deep-sea Trawlers and other Small Craft*, based on 20 years' experience, points out the benefit gained by the use of correctly applied metal spraying, particularly in modern trawlers where steel and light alloys are used. The paper discusses the advantages of metal spraying, not only on iron, but also on light alloys, which do not withstand corrosion as well as pure aluminium.

Metal sprayed coats being homogeneous, especially if the pores are sealed, to prevent moisture coming into contact with different metals used, may avoid galvanic couples being established.

This is one particular application for superstructures, accessories, and, broadly speaking, for many interior parts of ships.

Mr. Old draws attention to the fact that zinc seems to afford the best protection for fish holds, provided they have been designed for a metal spraying application. During the past 10 years, he has protected in this way some hundred holds where melting ice, sea water and organic liquids made a particularly aggressive environment.

This method also holds for tankers, which are sprayed with zinc or aluminium according to the nature of the liquid they are to carry.

The same applies on board for the installation for extracting cod-liver oil.

Although up to now, hulls have not been entirely metal-sprayed, Mr. Old believes that, in the near future, it will become standard practice, because of the enhanced efficiency of paints applied after metallization.

Of course, it will be necessary to revise maintenance methods in order that the metal-sprayed coating would not be spoiled.

He concludes by saying, in the light of many examples, it would be ridiculous to consider the price per square metre as the determinant. Collaboration between engineers engaged in trawler construction, including the corrosion and spraying engineer, will make it possible to build larger and better trawlers, with a three-deck superstructure, larger space for fish and machinery and using dissimilar metals where necessary.

In many cases, the actual metal-sprayed area is relatively small and the cost is kept low.

* * *

W. E. Ballard in his paper *Some Thoughts on the Economic Aspect of Metal Spraying*, does not share Mr. Old's opinion about the importance of the price of spraying. He maintains that it is not easy to calculate the actual economy resulting from metallization and that it depends on the scope in view : protection, repair, building up or surfacing worn pieces.

Economics of metal spraying present two aspects: one of the user and the other of the sprayer. What is of interest to the user is the price and life of the construction. If he builds, for instance, a structure the life of which must not exceed 15 years, he may neglect all protection, even a coat of paint. Final cost may be calculated in several very different ways : comparing metal spraying applied after sand-blasting and followed by painting, to painting by brushing, one will rarely find, if compound interest is taken in account, an advantage for

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Metal Spraying

(*Continued from page* 41)

metallization, especially in countries where cost of labour is low and corrosion slight. In spite of this, it appears that metal spraying, for protection and surfacing, is steadily developing.

The economic aspects of interest to the sprayer are the process itself and the equipment: sand-blasting in open or close circuit, mechanized or not, size of guns, nature and physical state of the metal to be sprayed, handling accessories, pressure and humidity of air, etc.

The author concludes that economy of the process is very much discussed and that exchange of information is still of great interest.

If it is true that the application of a process depends on its ability to satisfy technical requirements in the cheapest way possible, it may be said, with Z. Kowalski, in his paper *Standards Recommendations and Specifications about Metal-spraying*, that direct observation of the layer does not allow for qualifying the deposit. The efficiency of the coating will only appear after long service. The user is presented with a difficult problem, which can only be solved by indirect qualification. This is difficult because the scope of metallization is wide and the factors influencing the results are numerous. It is logical, therefore, to help the user establish standards, recommendations and specifications to enable him to check the process and the quality of the coating.

Many countries and institutions have established standards and specifications. Mr. Kowalski refers to 26 and, by means of tables, analyses these documents, classifying them in six groups:

(1) Protecting coatings against atmospheric corrosion.
(2) Refractory coatings.
(3) Surfacing.
(4) Materials for metal spraying.
(5) Hygiene of metal spraying operation.
(6) Symbols—Terminology.

The author points out contributions made by the Mechanics Institute of Warsaw and the Polish Standards Committee, and proposes some projects of standards to the Commission I W S—1.

The late Mr. Granjon, former manager of the French Institute of Welding, said that metal-spraying had become technical practice "through the back door". However, the important problem of qualified technical personnel arises and it suffers the same troubles that welding practice did some years ago.

* * *

A. Hedde and L. Lambeaux in their paper *Teaching Problems about Metal Spraying* lay out the reasons why teaching methods must be elaborated and the means to be used for the instruction of personnel, and suggest reading, human education and probation periods.

* * *

The same idea is suggested by Dr. G. G. Keel in his paper *Conception and Organization of Metal Spraying Course of Lectures in Switzerland*, and describes the work done by the "Association Suisse pour la Technique du Soudage". This institute organizes two courses for metallizers, the first one on anti-corrosive metallization with Zn or Al, the other on surfacing of steel, molybdenum, bronze and alloyed steels.

The first one is more popular for sprayers, the explanation being that Switzerland consumes yearly 150 tons of zinc.

The courses take three days, *i.e.*, 27 hours, of which ten are devoted to theory and the remainder to practical work. Seven metallization units have been installed in the Association's shops.

The author gives detailed programmes of these courses and says that the problem of skilled labour is easily solved.

Stretch-forming Test

(*Continued from page* 36)

properties. However, detailed application of this information, to individual cases of industrial presswork, still demands a sufficient analysis of the balance of requirements of strength and thinning within the stretch-formed zones of the particular component.

Acknowledgements

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I.M.F. London Section Dinner-Dance

THE London Branch of the Institute of Metal Finishing is holding its annual dinner and dance at the Café Royal, Regent Street, London, W.1. on January 14, 1961 at 6 p.m. for 6.30 p.m. Tickets 37s. 6d. each can be obtained from Mr. S. W. Baier, 9e, Cleveland Road, London, W.13.

MATERIALS FOR PRESS TOOLS

By A. G. SHAW *

(*One of a series of lectures presented at the Wolverhampton and Staffordshire College of Technology under the general title of "The Technology of Deep Drawing and Pressing.*")

Introduction

IT would be a very difficult task to cover the whole field of tool materials but it would not be fair to the title to confine this lecture to tool steels. It has therefore been decided to deal with what may be called the main groups of tool materials, these groups in order of discussion being:—

1. Epoxy resins.
2. Zinc-base alloys.
3. Aluminium bronzes.
4. Tool steels.

In this way it is felt that adequate justice can be done to the material involved and a fairly comprehensive picture of what can, or cannot be done by these grades of materials given.

Epoxy Resins

Plastics are a relatively new material in tooling, and they offer many advantages, but caution should be used when applying them in place of conventional materials. The type of material used is known as an epoxy resin the use of which is not confined to any specific tool. This type of resin is used for draw dies, rubber press formers, stretch-forming tools, drop-hammer dies, hand beating blocks and general tools for working thin-gauge material. They can be used for plastic forming tools and can also be used for jigs and fixtures. The properties of an epoxy resin compared with the conventional steels are very different, their tensile strength is low, the shear impact strength is low, they have very poor thermal-conductivity and the hardness is low. It is possible, by the use of suitable resins, to minimize the effect of these defects. However, tool design can often compensate for the low tensile strength and low mechanical properties of plastics. In order to overcome the weakness in this direction, epoxy resins are invariably used with a reinforced material, generally glass, but it can be asbestos; other materials have been tried and are being tried including metal filling. The effect of such fillers is to increase the rigidity of the plastic. It is probably well known that one of the inherent weaknesses of plastic materials when used for structural work is their low modulus of rigidity and their low modulus of elasticity, which means that to obtain the equivalent rigidity to that possible with steel, very thick sections have to be used. The use of reinforcement to some extent compensates for this and enables materials to be used in thinner sections.

The general use of epoxy-resin tooling is in its natural state, *i.e.* no addition to the surface is made. However, work has been done in the facing of epoxy resins with metals. This is done in a number of ways: by putting in a metal plate or, by spraying molten metal on to a negative surface of a mould and then building up with epoxy resin to form the tool body; this, of course, has the advantage of lightness and low cost coupled with a durable working face. The method has been developed in quite a large way for certain specified applications.

Resins, which are the basis of the process, are syrupy liquids and are converted into solids by mixing with a hardner. Generally speaking, this is a similar technique to that used in the car repair kits now being issued for general sale to the public. The change that takes place in the resin and converts it from a liquid into a solid occurs at room temperature and it is the result of a chemical reaction. The fundamental fact of this is that in a resin tool little or no shrinkage occurs, and this is of great importance when making accurate tools.

Mention has already been made to materials that are added to the resin to improve the properties. These are added according to the job required to be done by the tool. A tool shape, *i.e.* the required shape of the finished tool, has to be provided in order

* Uddeholm Ltd.

that the liquid resin will follow the form required. This is done by making a negative of the required surface; this form can be made from wood, plaster of paris, metal or clay. As the resin will only follow the surface it is placed upon, the surface needs to be extremely smooth and as accurate as is required in the finished tool. If the material is plaster of paris or a similar absorbant material, the surface needs to be sealed. Sealing can be done with a coat of wax which prevents the epoxy resin sticking to it. Patterns should be made to the precise dimensions as epoxy resins shrink only about 0.001 in. per foot. The volume change is about 0.025 per cent.

There are two main methods of producing epoxy-resin tools; first is the casting method and, second, is the laminating method. The casting method is the simplest as it reaches its required objective in one step whereas the laminating method requires the build-up of layers of resin, glass, resin, glass. However, where high strengths are required the laminate is superior. A laminate using glass cloth will give a flexural strength of 25 tons per square inch without difficulty and because of this, the choice of method must be considered fully when designing a tool. For instance, for jig fixtures or checking fixtures, light sections only are necessary and may be unavoidable from the nature of the component being checked. If a pure epoxy resin is used, then the strength of the jig will be of the order 4 or 5 tons per square inch and it could be broken without difficulty when used in a work-shop. By making such a fixture as a laminate then strength equivalent to that of mild steel is obtained and the jig can be handled without any fear of damage.

When a mould is required for the manufacture of plastic components it is usual to standardize upon a casting. If the mould is such that the thickness of the epoxy resin is more than 1 in. or $1\frac{1}{2}$ in., it is probably better and cheaper to use a cheap composition for the bulk of the tool and only the $\frac{1}{2}$ in. or so immediate to the working face needs to be of the high-strength material.

In a press tool an epoxy mix can have a resin-bonded sand core, *i.e.* using sand as the filling agent; the price of this material would be approximately £10 per cubic foot. This can then be faced with a resin/glass mix which may cost about £25 per cubic foot. These techniques can lead to substantial price savings on large tools. In very large tools such as foundry patterns and stretch-forming tools used for aircraft skins and anything which is not subject to heavy loading, economies can be made by using other types of plastic materials as low-density cores; polystyrene, phenolic resin and even wooden structures can be used.

Metals are used in combination with epoxy resins because of this basic and fundamental difference in mechanical properties. A press tool made in epoxy resin may be expected to give 20,000 pressings from 20-gauge material if the working surface is entirely epoxide resin and providing that radii of more than $\frac{3}{16}$ in. are used. Radii of around $\frac{3}{16}$ in. and lower will reduce the output from a tool considerably. Methods of overcoming the heavy wear which may take place on an epoxy resin tool are to provide metal working surfaces. It has been mentioned already that this is done by metallization; it is at present being widely used in the U.S.A. A second method is to use steel inserts and in this method blanking tools have been made where a steel blanking edge from the conventional tool steel is used and the backing mould of the epoxy resin is cast around it. This is an application which could have great possible cost savings. The cost of an epoxy-resin tool varies considerably but the makers of the epoxy resins claim that a completed tool will cost approximately 30 per cent of that of a conventional metal tool and, in some instances, savings of up to 90 per cent have been made.

There is no simple rule where it is possible to say that a plastic tool is satisfactory and can replace a metal tool but, generally speaking, plastic tools have a very limited application on anything but short runs. It can be the case that a simple tool such as a simple forming punch would be cheaper to manufacture in steel than in plastic. On the other hand, a complex face tool, such as that used for body panels in the car industry, would be cheaper to manufacture from an epoxy resin. Again, however, the quantities involved in the mass-production car trade are such that little use has been made of plastic materials on any scale worth considering. Nevertheless, it must be said that these materials offer a field of their own and it cannot be emphasized too greatly that this field is very often limited not by the materials but by the outlook of those using the tool materials and, just as there are applications where nothing but tool steel could ever be really successful, there are applications where epoxy resins have natural and commercial advantages and these applications need to be found.

Zinc-alloy Tools

The same arguments used to justify the use of epoxy resins for the manufacture of tools have been used for non-ferrous materials of the zinc-base type. They can be easily cast into complex shapes, the result being that only a small amount of machining is required to take care of shrinkage and dimensional alterations during solidification. A basis alloy is the Mazak diecasting alloy which is suitable with certain modifications. The Mazak alloy is basically Crown special zinc which is 99.99 per cent pure together with certain other elements—aluminium, copper and very tight compositional tolerances of three materials which have a very pronounced detrimental effect on the mechanical properties of zinc alloys; these are lead, cadmium and tin.

The results of these developments were two basic materials which are known as Kayem and Kayem2. The mechanical properties of these two materials are a little lower than mild steel in the case of Km material and about one-half the strength of mild steel in the case of Kayem2 material. However, it should be emphasized that these figures do not really indicate the behaviour of this type of metal in use.

The hardness of these two materials is interesting; Kayem material has a hardness of about 110 Brinell and Kayem2 a hardness of about 143 Brinell. It is probably true to say that the majority of usage of these materials has been in sheet-forming press tools. They have, however, been used for forming and drilling tools and for blanking tools and for this Kayem is usually used as a blanking die in conjunction with a hardened tool steel for the blanking punch. Bending tools are a good application and also drilling gates for rivet holes in aircraft sheets. Drilling jigs have been made in this zinc material and also holding jigs. In certain applications, these materials have been chromium plated to give them a hard wear-resistant surface and this technique can give significant increases in tool life. The use of these materials depends to a great extent on the severity of the operation and the type and size of material being formed. Generally speaking, in the case of light alloys being drawn or pressed from sheets thinner than 20 gauge, a life of over 10,000 pieces may be expected. In the case of stainless steel of a similar thickness, a life of or in the order of 3 or 400 pieces is all that is obtainable before the tool needs re-bedding. When used for the forming of mild-steel components, especially of the type used in motor-car bodies, several thousand can be expected from a pair of tools before re-conditioning is required. However, it must be emphasized that no strict rule can be applied outside the general specified conditions. Lives of over 150,000 have been obtained from tin-plated sheet pressed in Kayem tools in conjunction with a steel die ring. Again, it is felt that this material is one which must be approached with caution in some respects, but with spirit of adventure in others.

The economic advantages of these materials are, obviously, similar to that of the epoxy resins, *i.e.* the man hours required for tool preparation are reduced and the equipment cost is low. There is no waste because these alloys can be re-melted and re-used. Castings are easily produced and that can have great advantages in the present time when production schedules are very stringent and often a 2 or 3 day saving can make the difference of getting or not getting an order. Another advantage is that tools in such a soft material can be rectified very easily when compared with a hardened tool steel and because the cost of production is high it is som etimes possible to equal the life of a ferrous too by producing a number of zinc-alloy tools and obtaining the saving on the time to get the job into production. The main advantage of the zinc-alloy tools is that zinc is an excellent lubricant and it is quite true to say that this is probably the greatest attraction of these materials. Galling, which occurs in ferrous materials when forming aluminium alloys just does not occur when zinc-base tools are used. However, while galling is reduced maintenance of accurate form is also reduced and damage to the tool from foreign bodies can be severe.

Aluminium Bronze

The development of aluminium-bronze materials for press tools has received impetus because of the pick-up or galling which often occurs with tool steels when used to form stainless steel, Nimonic and mild steels to a certain extent. The requirements for such usage were a die material which was metallurgically dissimilar to the material being drawn and with surface characteristics which would reduce die pressure or, in other words, a slippery surface. It was found that aluminium bronze possessed two essential properties, it could be produced sufficiently hard to act as a tool for long runs and its surface was covered with a film of aluminium oxide which was both hard and slippery. The early work done with aluminium bronze showed promise but many difficulties were experienced; hardness was difficult to control; grain-size varied considerably and castings were often very brittle. However, the addition of various alloying elements (Mn, Fe and Si) to control the grain-size and the addition of tracer elements to act as an inocculent and produce fine structures even in the largest castings, finally enabled the manufacturers to produce a tool material which was successful as a commercial application. It is generally manufactured with a hardness of 400 Brinell and this hardness is in the " as cast " condition. In other words, no heat treatment is required to obtain it.

The strength of the material is rather contradictory inasmuch as the compressive strength is of the order of 95 tons per square inch but the strength in tension and in shear is relatively low, 45/60 tons per sq. in. in tension. This means that in order to obtain the best results when used in a tool set, it is essential that the die is completely enclosed by a retaining ring so that all the stresses on it are compressive. Although the hardness in the cast condition is high, about 400 Brinell, it is quite readily machined with carbide-tipped tools. The general requirement for machinability is the same as for the general machining of hard metal: the depth of cut can be high and is generally limited by power of the machine. The tool must be kept cutting as this material does work harden

quite rapidly and because it has a natural oxide layer, rubbing, once it does take place, will quickly dull the edge of the tool.

A weakness of aluminium-bronze alloys is the high shrinkage that occurs during solidification of a casting and because of this it is essential it is designed correctly and that great care is exercised in production. The material has its most successful use as a die in conjunction with a tool-steel punch. Very large quantity production has been obtained without surface deterioration, especially when forming the newer materials such as titanium, tantalum and molybdenum. It is often found that what required two draws in a conventional cast-iron tool, can be produced in one draw by the use of an aluminium bronze die.

Concluding this discussion on non-ferrous tool materials, it must be emphasized that their use should be done with caution and that the manufacturers consulted at all stages of initial investigations.

Tool Steels

It is now proposed to discuss the materials which form perhaps 95 per cent of the tools used in engineering to-day and that is the tool steels. Tool steels embrace hundreds of alloys from mild steel to the very complex tungsten-cobalt high-speed materials. Therefore, only tool materials used in deep drawing and pressing will be considered and detailed information can be given of a smaller group of alloys.

The most common material used in deep drawing and pressing in large components is cast iron. This may be an ordinary grey iron or nickel iron where greater strength is required. The cast irons have a number of natural advantages; they are easily cast to shape; the fact that they usually have large quantities of free graphite in their structure means that their lubricating properties are good; they are capable of reaching high hardnesses as under certain conditions they can be chill cast, which gives a surface hardness equal to that of hardened steel. The use of cast-iron tools has been very large in the motor-body-manufacturing field for pressings where the shapes are complex, the unit load fairly low and the production rate extremely high. There are no great difficulties with cast-iron tools and, generally, they are manufactured by specialists to order. Because there are no heat treatment requirements other than stress relieving, nothing is done to the tool other than to machine the surface to the finish required for the job being done.

The next material which is used very widely for deep drawing and pressing is case-hardened mild steel. This again is used for fairly large pressings with gentle radii and little demand on the material for high strength. Mild steel in the case-hardened condition provides two good characteristics, *i.e.* a tough core and a surface which is very hard and, consequently, has a high degree of "slipperiness."

The disadvantage of mild steel is, of course, that it has not the capability of withstanding high unit loads. What usually happens is that the core collapses and gives rise to a depression on the tool surface and it is when one moves into the field of the smaller pressings with very sharp radii and very deep draws that the selection of tool material becomes more critical and its use more exact because in the production of such components as cartridge cases and allied shapes very high bursting stresses are induced in the die and very high compressive stresses are imposed upon the punches. The modern tendancy for high-powered presses and high-speed production and the use of transfer presses has imposed greater requirements on the tool materials. However, even for such usage it is better to start at the less alloyed end of the tool-steel range and commence the selection from the cheaper material rather than to go straight to a more expensive and more difficult to machine highly-alloyed steel.

At this stage, it would be as well to generally look at the types of tool steels. They can broadly be divided into three groupings:—

1. The water-hardening steels.
2. The oil-hardening steels.
3. The air-hardening steels.

There are many alloys which fall within one or more of these groups and there are many alloys which can be used in two or three different ways. Within the first group, the water-hardening steels, come the straight carbon steels. These steels usually contain from between 0.4 to 1.5 per cent carbon and, according to the carbon content, so their use is determined. From a deep-drawing and pressing point of view, the usual material is one which contains about 0.9 to 1.0 per cent carbon and may contain, in addition, vanadium or tungsten. This material is normally used for dies and is not usually a good material to use for punches although it has often been used for punches, sometimes with great success but more frequently with tragic results. However, from the die point of view, it is an ideal material. It is capable of providing an intensely hard surface backed up by a very tough and strong core. When used as a die, the water-hardening carbon steels have one very desirable attribute and that is that when bore quenched, *i.e.* when the bore alone is hardened and the outside of the die and the top and bottom surfaces are allowed to cool naturally, very high compressive stresses have to be overcome during the use of the tool before the natural strength of the material is brought into play. This is a feature of water-hardening steels which is not thoroughly appreciated but is of great value in the production of shapes through open-ended dies

where very high bursting stresses are placed on the die and where very severe local heating is experienced due to the high speed transit of the material across the die surface.

The carbon steels have this one attribute and that is they expand again on cooling and this double expansion means that when the die is heated up and a jet of water is forced through the working orifice this cools down very rapidly and is fixed solid in effect. The outer mass of the tool being allowed to cool naturally, expands and acts, in effect, as a shrink ring on the hardened centre skin. The forces involved in this shrinkage can be of the order of 60 tons per sq. in. so that, in addition to the 100 tons or so available from the material, there is an additional 60 tons or so which has to be overcome; in this way, loads in excess of the normal strength of the material can be imposed.

Tool designers and tool makers frequently utilize steels for drawing dies for this class of work that are far more expensive than is necessary and are often not as efficient as a properly-quenched water-hardening steel. It must be emphasized, however, that the usage of this type of material and that type of quenching is limited to definite types of work as mentioned and that the wrong application will lead to no improvement in life.

The next use of water-hardening steels is for straight die shapes without orifices and for general forming or drawing. In this case, it is really a matter of deciding the severity of the operation in question. In general, however, it can be said that, for long runs under arduous circumstances and normal press-shop conditions, the water-hardening steels give excellent service for many jobs but for maximum tool life the water hardening steels then need to be replaced by the oil hardening range of steels, which may be classed as low alloy though, here again, the division is elastic and certain oil-hardening steels are extremely high-alloyed. There is one group of steels which come in this category that probably form the greater part of material sales in this country and that is the carbon/manganese/chromium steels. These are a group of steels which have very attractive properties:—

(*a*) they are reasonably cheap;

(*b*) the average price of steels in this class varies between 1s. 6d. and 2s. 6d. per lb. dependent upon the alloying content;

(*c*) they are easy to heat-treat and oil-quench at temperatures of the order of 820° C.;

(*d*) they are readily machined so that the most complicated shapes can be easily cut;

(*e*) they are very stable in heat treatment so that size changes are not a serious problem.

The basic analysis is carbon/manganese/chromium; the standard original analysis was 1 per cent C, 1 per cent Mo, 1 per cent Cr. However, many variations on this exist, one of the most useful being where the chrome content is reduced to 0.5 per cent and an additional 0.5 per cent of tungsten is introduced into the steel; this class of steel is of great interest from a deep-drawing and pressing aspect as the tungsten imparts a high degree of wear resistance to the surface.

These steels will do most of the drawing and pressing jobs that are met in industry. It is often the case that the oil-quenching steels will be used in conjunction with the water-hardening steels, the water-hardening steels being used as the die and the oil-quenching steels being used as the punch, the reason for this being, that, in general, the greatest compressive stress in a deep-drawing occurs on the punch and, therefore, a high core strength is required.

A good-quality oil-hardening steel within the section of 1 in. to 2 in. diameter will harden up to about 62 Rockwell and will normally be tempered to 60 Rockwell for punch usage. Where oil-hardening steels of the carbon/manganese/chromium type are used for dies for deep drawing and pressing, again a hardness of around 60 Rockwell is desirable.

In the very severe types of draw using high-speed presses and with a sometimes not very well finished component material, the air-hardening steels provide the luxury class of materials. These steels are basically carbon/chrome steels where the carbon content varies between 1.2 and 2.0 per cent and the chromium content varies between 12 and 15 per cent. These steels have great hardening properties and will air harden in very thick sections to a Rockwell of the order 60/62. In thin sections, Rockwells of the order 64 can be obtained in the air-quench condition. However, again, these are steels which can also be classed as oil-hardening steels because for maximum hardness in the thicker section oil quenching is usually done.

These steels are widely used for such things as the deep drawing of stainless steel, the deep drawing of nickel-containing alloys generally and the deep drawing of aluminium. Due to their high hardness and high alloying content the surface responds very well to continued usage and drawing and pick-up are reduced to a minimum.It is well to mention at this point that for this type of steel other alloying elements are sometimes used; tungsten is added to give a high degree of surface wear resistance. In others, cobalt is added, again to give wear resistance and high strength, and in some steels nickel is added to increase its toughness.

Lubrication

Surface " slipperiness " is a term that has been used to denote the property of the surface to resist pick-up between itself and a surface it is being run against. Scoring, galling and pick-up, result when welding takes place between the surface of the work

and the surface of the tool and this welding occurs when the lubrication film breaks down. Therefore, the prime requisite for successful deep drawing with any tool material is to maintain an adequate tool lubricant. However, it is regrettable, but true, that in many press shops lubrication of tool and of work is done in a very slap-dash manner. Often, a mere wipe with a piece of rag coated with what may once have been a lubricant is done by the operator. It is essential, therefore, to use tools where the surface is an unresponsive to pick-up as is possible and there is no doubt about it that the tungsten containing high alloyed steels offer the best freedom from such troubles.

There are ways of helping the steel by means of other than an added lubricant, typical of these being the use of surface treatments of a nature in which either the chemistry of the surface is changed or a barrier is formed. A prominent method which is finding success is the Sulphinuze process. In this process, sulphur is introduced into the surface of the steel and reacts to form a sulphur-rich layer of a few tenths thickness. This layer gives remarkable freedom from scuffing and pick-up. The author has had experience of a number of instances where this treatment has made the difference between very long runs without any trace of surface deformation and runs of low production quantities where the tools have to be cleaned up at frequent intervals.

Another method used quite successfully is to phosphate coat the tool. This phosphate coating converts the surface of a steel to a phosphate which has the property of absorbing a very large quantity of oil in relation to surface, about five times that which could be absorbed by an untreated surface. This means that a better protective film is kept between the work and the tool than is possible by conventional methods.

Another answer to this problem has been the development of very efficient lubricants by many of the firms specializing in this field and it is most essential to realize that the tool must be helped by the choice of adequate lubrication, correct lubrication and also by cleanliness in the press shop. This is a problem which all firms engaged in deep drawing and pressing come up against all the time.

It can be said that far more damage is caused to tools by foreign matter which is either present on the material being pressed or is floating around the press shop as airborne particles, than occurs due to true scuffing or pick-up between the working surface of the tool and the material being pressed.

Nitriding is a process which is of great benefit in the highly alloyed steels for increasing the natural slipperiness of an alloyed steel and again reducing the tendency to pick-up. Hard chrome plating has also been used with great success. However, both these treatments have one defect common to both and that is they can flake and once they flake then the damage to the tool is intensive.

Finally, it is necessary to consider the tungsten carbides. These materials are not steels; they are sintered from powder and have remarkable hardness and, in applications for very high production runs in the order of millions, it will often pay to invest in the high cost of tungsten carbide to obtain a degree of freedom from pick-up and wear which is little short of outstanding. It has been shown that tungsten-carbide dies, in given applications, outlast conventional tool steels by many more times than that necessary to amortize the original high cost.

There are, in conclusion, a few basic rules worth remembering for the successful application of tool steels to deep drawing and pressing:—

1. Consult your steel supplier when the tool is in existence only on paper for his advice as to the most suitable steel to use.
2. When you have that advice, use it.
3. When the tool is being made, leave adequate allowance for cleaning up after heat treatment.
4. Leave adequate production time for heat treatment.
5. See that the tool is given the same care in heat treatment as it has received in manufacture.
6. Use the tool under conditions suitable for the material recommended.

Acknowledgement

The author expresses his thanks to Mr. A. W. F. Comley for his invaluable assistance in the preparation of this paper.

NEW HOME FOR BIRMINGHAM ENGINEERING CENTRE

IMPORTANT developments are about to take place at the Birmingham Engineering Centre. In mid-1961, a move will be made to new premises, the former Masonic Hall in Broad Street, Birmingham, a building most prominently situated in the City's new civic centre area and well known as a Birmingham "Landmark". It will provide more than double the Centre's present area and will enable our long overdue expansion to take place.

Layout plans are being drawn up at the moment and will in due course be circulated to exhibitors to enable sites to be selected in the new building for the transfer of exhibits. With 1960 building rentals and the large additional area it is inevitable that general costs will be increased but the Engineering Centre does not distribute profits and its policy will be to maintain exhibition space rentals at the minimum consistent with running costs.

In addition a Building Centre is to be developed side by side with the Engineering Centre which will give to both the considerable advantages of complementary publicity and attendance.

An Introduction to the

THEORY AND PRACTICE OF FLAT ROLLING—5

By the late C. W. STARLING, B.Eng., A.M.I.Mech.E.

(*Continued from page* 916, *December*, 1960 *issue*)

FORCES ON THE MILL HOUSING

The Elastic Curve

IN the previous chapter, roll spring due to roll bending and flattening was discussed and it was shown that the effect of this spring is to increase the roll gap when the bar enters the rolls. After the bar leaves the rolls the gap returns to its original setting. This is, therefore, an elastic spring as there is no permanent deformation of the rolls and the curve of roll spring against roll load is the elastic curve for the rolls.

In a rolling mill there must be bearings and some sort of bearing housing to support the rolls and, under the heavy rolling loads applied, there will be an elastic distortion of these bearings and housings. It is, therefore, possible to plot a similar spring/load curve for the elastic spring of the housings and bearings.

Forces on the Conventional Housing

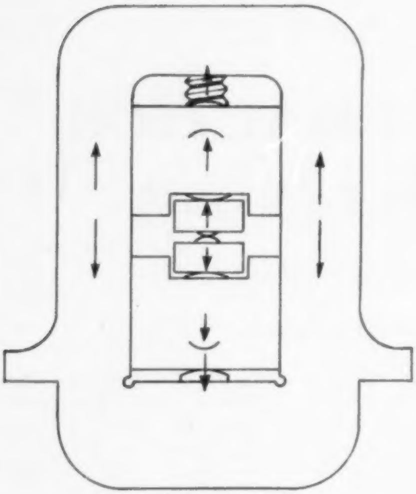
In the earliest days of rolling, a pair of crude rolls was used and the mill housing was the simplest possible arrangement for holding the rolls in the correct relationship to each other. The bottom roll was held in simple fixed bearings and the top-roll bearings were located between side pieces which allowed vertical movement of the roll. This vertical movement was restrained and the correct gap set by means of wedges hammered between the bearings and the cross piece above the side supports. This basic layout has survived almost unchanged for centuries and it is only recently that the quest for higher precision has brought forward new types of mill housing.

The development of the simple housing has consisted chiefly in making much stiffer and heavier frames together with detailed improvements in bearings and chocks and in roll-gap adjusting gear. For the last fifty years housing design has been virtually unchanged and variation between the different manufacturers is small. A typical modern housing, being a very heavy casting with machined side posts, is shown in Fig. 18.* One chock fits snugly in the bottom of the housing window, whereas the other chock is free to slide vertically between the side posts. The chocks are usually prevented from moving endways by pads bolted to the face of the housing posts. The housings are designed for stiffness rather than strength and in a cast iron housing it is usual to stress the posts to only ½ ton per sq. in., which is increased to between ¾ and 1 ton per sq. in., for cast steel housings. Even though the stress in a housing is so low, it is not unheard of for a housing to break under the extreme loads arising from a cobble in the mill, one of the most common failures being at the change of section in the top bridge, where the screw passes through the housing.

The qualitative distribution of forces in a housing of this type is shown in Fig. 97. The full rolling load is taken by the roll-neck bearings, which are supported in chocks; the bottom chock usually rests on a spherical pad which in turn is supported by the bridge piece; the top chock usually has a spherical seating on the screw. Fig. 97 shows how the full roll load is then applied between the screw and the bottom bridge. This load imparts a tensile stress to the vertical pillars, a compressive stress to the screw and causes bending of the top and bottom bridges. Because of the bending of the bridges the posts will tend to bend inwards and the way in which the housing distorts depends on the relationship between the resistance to bending of the vertical posts and the resistance to bending of the bridges. If the posts are rather slender and the bridges heavy, the bending of the bridges will be small, but there will be considerable waisting of the posts, as seen in Fig. 98(a). On the other hand, if the posts are heavy and the bridges are light, the bridges will bend considerably, but will tend to bend as a built-in beam and there will be little bending of the posts, as seen in Fig. 98(b).

Calculation of housing deflexion due to the rolling load is difficult, as housings may be a complex shape, particularly when part of the screwdown gear is cast into the top bridge. One method is to

* *See Sheet Metal Industries*, October, 1960 issue (p. 756).



treat each housing as a chain link and apply a conventional formula for chain link deflexion. This assumes a constant cross-section in the link and the work involved is not justified by the accuracy obtained. Other investigators have suggested graphical methods which can be used for any shape of link and although these are lengthy and difficult to use, they can be very accurate.

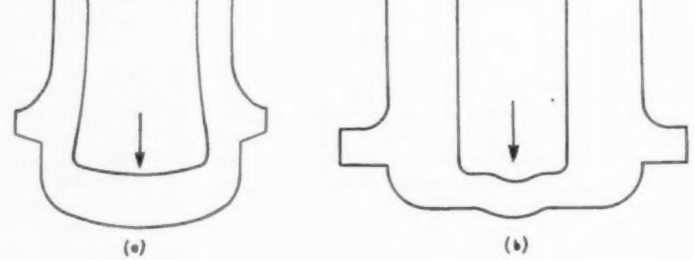
For an estimation of mill modulus in practice it is usually sufficiently accurate to use simple approximations to obtain the housing deflexion. To do this it is assumed that all the rolling load is applied vertically through the housings and the increase in length is calculated by normal methods. Similarly, it is assumed that the rolling load is applied to each bridge and the bending of the bridge obtained from the simple beam formulae. The problem is to decide which beam formula to use, and it is found in practice that something between the formula for a simply supported beam and that for a built-in beam should be used. Some discretion should be used in deciding on this and if the bridge is heavy compared to the posts, it will obviously approach more nearly to the simply supported state than will a bridge which is light compared to the posts and which will approach the built-in beam. The compression of the screw and chocks can be calculated and allowance must be made for flattening in the bearings and roll necks. The total deflexion will be the sum of the deflexions of each component.

From this calculation it will be seen that the relationship between deflexion and load for individual components is a straight line, except for the roll-neck bearings and the spherical pads above and below the chocks. The graph of total deflexion against load is, therefore, a straight line with a negligible curvature due to the bearings and roll necks.

It will be seen from the foregoing that although the stresses in the various components are low, each component is of such a length, particularly in four-high mills, that the deflexion of the housing becomes appreciable. It is quite common in a medium size four-high mill of say 400 to 500 tons capacity to have a maximum housing deflexion at full load of 0.040 in. If the spring is less than this it would be called a "stiff" mill. It is also found that when the load is small the various components settle down and take up clearances and any uneven-

Fig. 97 (above).—Distribution of forces in a housing showing how the rolling load is transferred through the back-up bearings to the housing bridges

Fig. 98 (right).—Deflexion of different mill housings under load. (Greatly exaggerated).



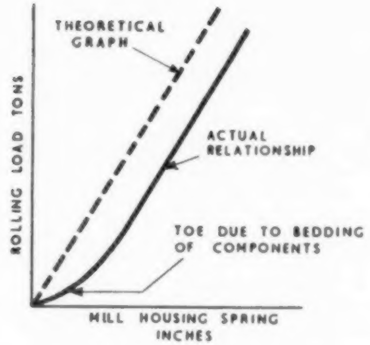
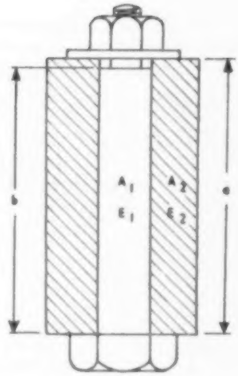


Fig. 99 (left).—Graph showing the relationship between rolling load and housing spring

Fig. 100 (right).—Bolt through a cylindrical block prior to pre-stressing the block



ness in mating surfaces, giving the graph a pronounced toe, as shown in Fig. 99.

There have been reductions in commercial tolerances in recent years and this trend is continuing so that the modern mill must be a high precision machine. The design of the conventional housing does not lend itself easily to any increase in precision and some manufacturers are investigating the possibility of quite revolutionary designs in which there are as few parts as possible and they are kept as small as possible to make a very stiff mill.

The Bolted Chock Housing

In an effort to reduce the number of parts and keep the stressed components as short as possible, so increasing the stiffness of the mill housing, one manufacturer has taken it to the ultimate conclusion and eliminated the housing completely. In this case, heavy chocks are bolted together directly and adjustment of the roll gap is carried out by means of bearings in eccentric sleeves. The calculation of deflexions in this "housing" is quite straightforward. The rolling load is applied to high-tensile bolts connecting the chocks and the extension of the bolts can be calculated in the usual method using Hooke's Law. The flattening of the roll neck and bearing can be calculated as in the previous example and if properly designed, bending of the chock will be negligible, although there will be a small amount of compression of the chock between the bearing and the top face in contact with the bolts. Mills of this type have been built and used successfully, but for high-precision flat rolling it is essential to use relatively small work rolls and while it is a very simple design as a two-high mill, it becomes a little more complicated when built as a four-high, but still has many advantages over the conventional housing.

The Pre-Stressed Housing

The possibility of reducing the spring of a conventional mill housing by passing high-tensile bolts through each vertical post has been considered. These bolts are tightened to give a pre-load greater than the normal rolling load and variations of this, such as separate bridge pieces held to the posts by pre-loaded bolts, have been investigated and a small number of mills built.

There is a great deal of controversy over the effect of pre-stressing on mill spring, and a common fallacy is that the spring of pre-stressed housings is zero. In actual fact the spring is only reduced in so far as the high-tensile bolts have a higher Young's Modulus than the cast iron or cast steel posts. The effect of pre-stressing can be shown by considering the case of a simple block of steel with a bolt through it, which has been discussed by Southwell. His explanation is rather mathematical and it is sufficient in this chapter to quote the results.

Fig. 100 shows a bolt passing through a metal block with a nut screwed up finger tight.

Then,

a = the initial length of the block.
b = initial length of the bolt.
A_1 = the cross-sectional area of the bolt.
A_2 = the cross-sectional area of the block.
E_1 = Young's Modulus for the bolt.
E_2 = Young's Modulus for the block.

If the nut is tightened to give a load F in the bolt, it must be balanced by a load F in the block and it can be shown that

$$a - b = \frac{aF}{A_2E_2} + \frac{bF}{A_1E_1} \quad \ldots \quad \ldots \quad (22)$$

and from this, if a and b are known, it is possible to calculate F; alternatively for a required pre-load F, b can be calculated.

If this composite block is now considered as a single unit with internal force F, an external force P can be applied to it, as shown in Fig. 101. The application of P causes the composite block to expand a distance ε. In applying this to a rolling mill, the curve of mill spring against rolling load is required and a similar expression can be obtained in

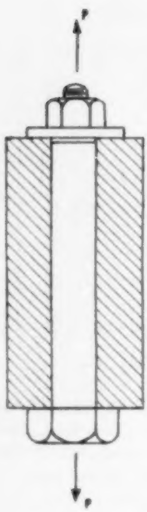


Fig. 101 (*left*).—*External load P applied to a pre-stressed block*

Fig. 102 (*below*).—*A composite pre-stressed block with an external load*

the case of the composite block, relating extension ε to external force P.

This is :—

$$\frac{P}{\varepsilon} = \frac{A_2E_2\,(A_1E_1 + A_2E_2)}{a\,(A_2E_2 - F)} \quad \ldots \quad \ldots \quad (23)$$

If required, when there is a preload F and an external force P, the final forces on the bolt and the block can be obtained from the following equations.

$$\text{Load on bolt} = F + \frac{P(A_1E_1 + F)}{(A_1E_1 + A_2E_2)} \quad \ldots \quad (24)$$

$$\text{Load on block} = F - \frac{P(A E - F)}{(A_1E_1 + A_2E_2)} \quad \ldots \quad (25)$$

From equations 22 to 25 it is possible to draw the following conclusions.

(1) Provided there is a preload on the composite block, the external force required to stretch the block by a given amount is exactly the same as the sum of the forces which would be required to stretch the separate, unstressed block and bolt by the same amount.

(2) For all practical purposes, the relationship between P and ε is independent of the magnitude of preload F.

It will be seen from equation 23 that F only appears in the term $(A_2E_2 - F)$. As A_2E_2 is a very large quantity compared to F, the equation will give the same answer, to normal limits of accuracy, if F is left out completely.

Translating these into terms of rolling-mill spring, it will be seen that in a pre-stressed housing, the magnitude of the pre-stress is unimportant, provided that it never falls to zero during rolling.

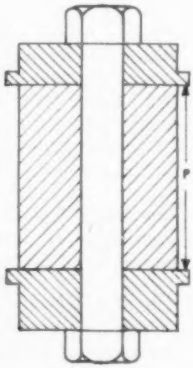
As a given external force stretches a pre-loaded block the same amount as this force would have stretched the separate block and bolt without pre-load, it follows that the only advantage of the pre-stressed housing over the solid housing lies in the higher value of Young's Modulus for the bolt. There is also the point that the initial bedding down and taking up of clearances in the normal housing is eliminated.

It will be seen, however, that the pre-stressed housing will be much stiffer than a similar bolted chock construction with no pre-stress, as in this construction the rolling load is resisted by the bolts only, whereas in the pre-stressed housing the spring is the same as if the rolling load was resisted by the cross section of the bolts plus the cross section of the housing under the pre-load.

Before applying this simple theory to an actual mill design, consideration will have to be given to a slightly more complicated case in which the block is in three parts and the external force is applied between the outer blocks, tending to force them apart, as in Fig. 102. This has been published elsewhere by the author.

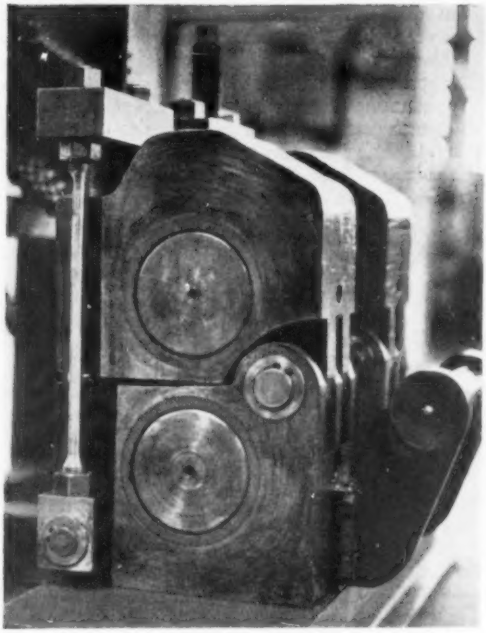
The pre-stressed housing and bolted chock type of design is now being accepted by mill operators, but in designing new mills for special applications, there is a great deal of conservatism and both designers and customers still insist on the conventional type of mill. Basically, in designing a rolling mill the first consideration is the size of the work roll required to do the work and the type of backing up that it will need. The rest of the design consists then of providing a means of holding the rolls in correct relation to each other with a suitable method of adjusting the roll gap either manually or automatically. A designer who is not hidebound by convention then has a wide field of designs to choose from. A simple type of hot-rolling mill, named the Hinge mill, was designed and built by the author for a special application at the British Iron and Steel Research Association's laboratories and this is described briefly as illustration of the method of calculating the stiffness of any mill, which is rather unusual in design.

The Hinge Mill



The Steel Making Division of the British Iron and Steel Research Association had a project which required a small rolling mill to carry out special duties and although the details of this project are irrelevant, an outline of the requirements is given to show the reason for this particular design.

A small portable mill was required which would be capable of rolling 1½-in. to 3-in. wide strip at speeds



varying from 100 to 200 feet per minute. This mill was required to roll hot mild-steel strip from $\frac{3}{8}$ in. to $\frac{3}{16}$ in. thick in one pass and on occasion it was expected that it might be required to roll from $\frac{3}{16}$ in. to $\frac{1}{16}$ in. in one pass at a temperature of approximately 1200°C. Because of the nature of the project with which it was concerned, it was expected that there would be considerable variations in ingoing gauge, possibly of the order of $\pm\frac{1}{16}$ in. on a $\frac{3}{16}$-in. nominal thickness and the mill would be expected to take out these gauge variations as far as possible to give a uniform outgoing gauge.

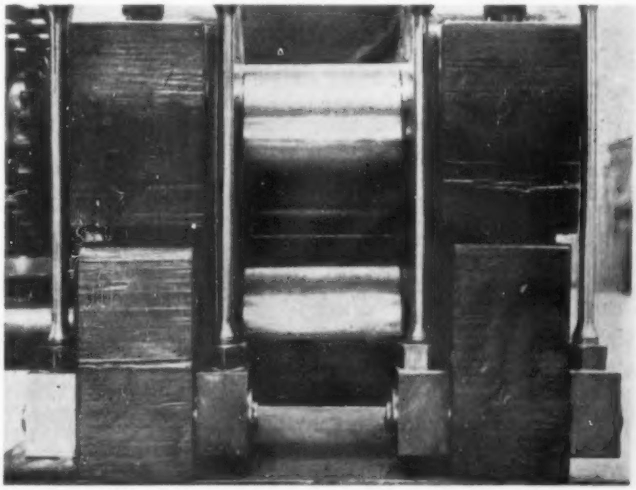
Because of the need for portability, the mill had to be as small as possible consistent with the loads required, and because of the gauge variations it was required to be as stiff as possible. An interesting feature is that although the mill had to be very stiff for rolling, it was also to be used for pulling strip, for example, only $\frac{1}{16}$ in. thick, with a sudden increase to $\frac{3}{16}$ in. thick, which had to be rolled down to the original $\frac{1}{16}$ in. This required a very soft mill during the pulling operation, suddenly reverting to a very stiff mill during rolling. After considering various possibilities, the mill was designed on the hinge principle, as shown in Fig. 103.

The maximum design load was 60 tons with provision for a further 25 per cent overload. After deciding on a suitable roll size the roll-neck size was calculated to give the correct loading on plastic bearings which were mounted in chocks profiled from thick steel plate, as shown in the illustration. Tongues were machined on each chock and interlocked on a pivot pin, which also can be seen in the photograph. The lower chocks were then bolted rigidly to a base plate and a breast roll fitted, as shown. The roll gap is adjusted by means of screws operating through a cross-piece attached to high-tensile bolts pivoted to the bottom chock, as shown in Figs. 103 and 104.

This brief description gives the main features of the design, and the method of calculating the stiffness of a mill of this nature can now be considered. The rolls are large in diameter in relation to the length, with substantial necks, and as the chocks are massively built in relation to the maximum load, with a heavy pivot pin, it will be seen that most of

Fig. 103 (above).—General view of the Hinge mill

Fig. 104 (right).—Front view of the Hinge mill showing method of adjusting roll gap



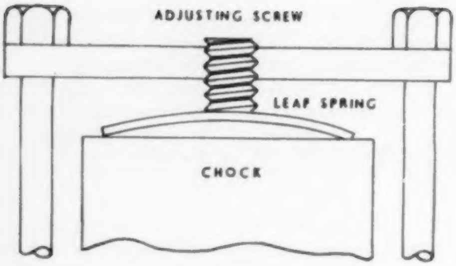
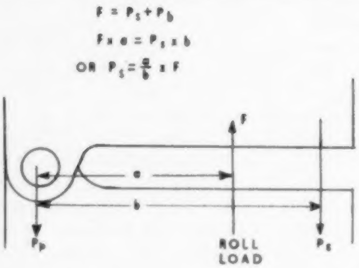


Fig. 105 (*above*).—*A Hinge mill with a leaf spring to give a high initial spring*

Fig. 106 (*below*).—*Method of calculating the forces on the pivot pin and adjusting screw in a Hinge mill*

Fig. 107 (*right*).—*Method of calculating roll spring from the spring at the pivot and adjusting screw*

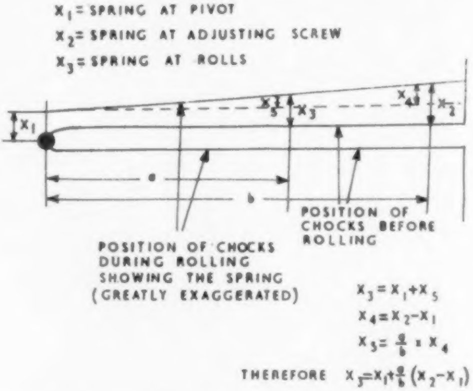


the mill spring is in the saddle carrying the adjusting screw. It is apparent then that it is possible, by adjusting the diameter of the side rods of the saddle, to make the mill spring almost anything which may be required. Another interesting feature is provision for varying the stiffness of the mill during rolling. If a strong leaf spring is inserted between the adjusting screw and the chock, as shown in Fig. 105, the modulus of the mill will be controlled by the stiffness of this spring, until it flattens completely and the screw comes up against the chock, after which the stiffness is controlled by the side rods.

In calculating the stiffness of a mill of this type, for simplicity it can first be assumed that the chocks and pivot pins are so heavily built that they are taken to be infinitely rigid.

The rolling load will be balanced by the reaction on the pin and the force on the adjusting screw, and as these three forces are all vertical and there is no other force in the system, they must balance. The force on the adjusting screw is obtained by taking moments about the pivot pin, as shown in Fig. 106 and subtracting this force from the rolling load gives the vertical reaction on the pivot pin.

Having obtained the force on the adjusting screw, the spring in the saddle and screw can be calculated by assuming that the side rods are in tension and that each carries half the total force on the adjusting screw. The compression of the adjusting screw can be calculated and the bending of the bridge which carries the screw. In this case the bridge will



approach the simple case of a vertically supported beam with point loading at the centre.

The spring in the pivot pin can then be calculated by a straightforward application of Hooke's Law. Having obtained the spring at the pin and the spring at the adjusting screw, the spring at the rolls will be equal to the spring at the pivot pin, plus a proportion of the difference between the spring at the pivot and the spring at the adjusting screw ; this is made clear by Fig. 107.

If the spring is calculated for various rolling loads a graph of load spring can be obtained.

The Elastic Curve for a Mill

The spring in work rolls and backing rolls due to bending of the rolls and flattening at the various points of contact, has been discussed at some length in Chapter 4.* When considering the elastic curve for a mill, the total spring due to the rolls must be added to the total spring of the housing, together with any deflexion at the roll neck bearings.

The calculated relationship will be very nearly a straight line, as almost all the factors are obtained from Hooke's Law or from the bending of beams, in which case the spring is directly proportional to the load. In the case of the roll flattening, however, the deflexion is not directly proportional to the load, but there is a slight curvature. The resultant calculated relationship between mill spring and load

(*Continued in page* 55)

* *See Sheet Metal Industries*, December, 1960 issue.

(*Continued from page* 54)

will then deviate slightly from the straight line, because of the flattening of the rolls and flattening at the roll neck bearing. In practice, there may be a substantial spring when the load is first applied, depending on the housing design and it is virtually impossible to estimate the extent of this effect giving a "toe" to the curve.

If a mill is fitted with some means of measuring the rolling load, it is a simple matter to plot the mill spring/load curve by direct experiment.

Mill Spring can be defined as the difference between the initial roll gap and the actual rolled gauge. If S is the gap between the rolls before the entry of the bar and h is the gauge of the rolled bar, the mill spring will be h-S. This will still apply if the rolls are in contact before the entry of the bar and even if they are forced together before the entry of the bar. If the rolls are just touching before entry, S will be zero and the mill spring will be h. If the rolls are forced together under a pre-load, then S will be the distance moved by the screws after the rolls contact each other and will be negative. For example, if the screws are run down 0.020 in. after the rolls make contact, S will be -0.02 in., then the mill spring $= h - S = h - (-0.020) = h + 0.020$ in.

In order to plot the load/spring curve, it is then only necessary to run the mill with no material between the rolls, under different degrees of pre-load, and measure the rolling load for each screw position. This can be plotted directly as the load/spring curve for that particular mill.

Although this is a very simple test to carry out, the curve which is obtained will not be truly representative of the mill spring when material is being rolled. When a bar or sheet is being rolled, it is usually substantially less in width than the roll barrel length and the rolling load is, therefore, concentrated over part of the rolls, causing roll bending and flattening, which will be greater than that obtained when the rolling load is spread over the whole width of the roll barrel, as when there is no material in the rolls.

The load/spring curve is usually assumed to be a unique, reversible and reproducible curve for a given mill, but this is not quite true as the curve will vary slightly with every different width of material rolled, because of the above-mentioned variation in load distribution on the rolls. Provided the mill is fitted with loadmeters, it is not difficult to plot a series of mill spring curves for different widths of material being rolled. One method is to set the rolls at a known gap, which is carefully measured by slip gauges and enter bars of various thickness, each being of sufficient length to enable rolling conditions to stabilize. The outgoing thickness of each bar corresponding to the steady load condition is then measured and the difference between the measured thickness and the roll setting will be the mill spring for that particular load. This method is quite satisfactory and gives the load/spring curve for a given bar width, but the range of load which can be obtained from a given roll setting is limited by the range of thickness of the bar which will enter.

An alternative method which is a little more tedious, but can be used to give the complete range of the curve from minimum to maximum load of the mill, is to use a fixed thickness of bar entering the mill and change the roll setting for each bar. As before, the roll setting must be measured carefully and the final rolled gauge measured, the difference giving the mill spring for that particular load. In practice, it is sufficient to obtain the roll setting at each point in the test directly from the screw position. This will give the correct form of the mill spring curve and if the roll gap is measured accurately at that point, the position of the curve in relation to the zero of the graph can be established.

This has been discussed at some length by Huggins.

(*Series to be continued.*)

PRIVATE TRADE AND TECHNICAL DELEGATION TO RUSSIA

THE first privately organized trade and technical delegation to visit Russia since the war, left London Airport on December 8 last. Members of the party were to lecture to groups of 50 to 60 Russian technicians and engineers on the machinery and equipment which their companies manufacture. They also visited Russian factories in Moscow, Leningrad, Kief and industrial areas in the Ural mountains. The visit was organized by Mr. Greville Wynne, an industrial sales consultant who specializes in East European markets. An official reception for the party was given at the British Embassy by the Ambassador to Moscow, Sir Frank Roberts.

One member of the party was Dr. A. D. Merriman, who is scientific adviser to Edgar Allen and Co. Ltd. of Sheffield. Mr. W. J. MacBride, technical director to the same company was also in the party. Other members of the group were: Mr. R. R. M. Magnier, Barry-Wehmiller Machinery Co. Ltd.; Mr. S. H. Richards, Marshall Richards Machine Co. Ltd.; Mr. J. H. Winterbottom, Mr. N. Marsden and Mr. C. Hall, Turner Machinery Ltd.; Colonel E. C. MacKeller and Mr. J. B. Bailey, Westool Ltd.; Mr. B. S. Matthews and Mr. C. E. B. Cooper, John Thompson Ltd., and Mr. N. Kirkwood, Richardsons Westgarth and Co. Ltd.

I.S.M.E. Discussion

(*Continued from page* 24)

sub-critical anneal. It was preferable to anneal, cold work and then, if necessary, anneal again. This second annealing, following the cold work, produced the necessary grain recrystallization. The structure of the material from the mill was not important as long as it was not grossly overheated. The effect of after-mill cooling was corrected as a matter of course.

Attitude of Steel Suppliers

Mr. Rogers (Hadfields Ltd.) said that it was to be expected that during the course of the conference one or two broadsides would be fired between Sheffield and Birmingham, and this would be one of the highlights. It was not his intention to anticipate some of those mighty broadsides but he would just like to get the field of battle clear. Mr. Okell had mentioned the question of the supply of steel and the various things that had to be right about it. He was himself a metallurgist, not a commercial pundit —if he might use the expression—but he had noticed that the aspect of price had not been dealt with. It had been borne in on him in Sheffield—some people might not agree with him—that the desire of the cold forging industry was to get two qualities, or requirements, which had been synonymous—the best, and the cheapest.

He did not think anyone would dispute that in Sheffield one was in the centre of expert metallurgical opinion. He would invite everyone interested in the cold-extrusion process to please use it, but not come with problems unless basic information could also be given. Mr. McKenzie had mentioned a very pertinent aspect of this general problem—the air of mystery. There was no doubt that there was a real Pandora's Box here. Steel was supplied but the suppliers heard nothing further of it. Even when they asked how it had turned out they were told no more than that it had done reasonably well. In such conditions, how could Sheffield be expected to help?

It was Sheffield's endeavour to offer tool steels capable of withstanding compressive stresses of 160 tons per sq. in., and that during the conference there would be a common front on the problem to be faced in the selection of tool steels. He would expect those who were engineers of the process to give some indication of what was wanted—not simply say, "We want a steel that will do the job". One had to think in more definitive terms, *e.g.*, of applied stress.

On the question of fatigue, it was well known in all engineering applications that fatigue strength of a component could be considerable affected by surface stresses and, of course, this technique was used in the manufacture of pressure vessels and in the shot peening process.

Mr. Okell said that Sheffield specialized in the making of steel and he would not like to tell it how to do that. He merely asked for good steel. It would then be processed.

He would just mention that Mr. Rogers' company did very well so far as the quality of steel was concerned! He had, after all, mentioned that a good many modern mills turned out excellent steel, but some did not, and the specification had to cover these. If one of the good mills turned out a product that was below the ordinary standard there was still the specification to fall back on and, up till now, the user industries had had to take anything that the steelmaker cared to produce. This might or might not alter, but all the user wanted from Sheffield was steel of good physical quality and free from defects. Given this, he would not argue about most other things—except the price.

NEW STEEL COMPANY FORMED

THE Firth Cleveland Group has formed a new company, Firth Cleveland Steel Ltd., with Registered Offices at Wentworth Street, Sheffield. The company will operate from Holmes Mill, Rotherham. The chairman is Mr. C. W. Hayward, chairman of Firth Cleveland Ltd. The managing director, Mr. John Tonking, defines the purpose of the new company as follows:—

" Firth Cleveland Steel Ltd. has been formed with the object of ensuring that the customers of J. J. Habershon and Sons Ltd., The Tenuous Steel Co. Ltd. and Firth Cleveland Steel Strip Ltd. reap the benefits of the potential of these three companies which are now operating in the closest touch with each other to provide a wide range of specialist steel strip.

" Orders placed with Habershons, Tenuous and Firth Cleveland Steel Strip will continue to be executed by these companies as separate manufacturing companies and there will be no break in the continuity of association between customer and the individual companies concerned. All customers will, however, benefit from the close technical and administrative co-operation between the three companies.

" Overall responsibility for the selling function of Firth Cleveland Steel is vested in Mr. Eric W. Day as sales director. At the same time, Mr. Allen E. Gilbert as the sales director of Habershons will continue to be responsible for the special interests of Habershon's customers. All area sales managers and sales representatives have been transferred to Firth Cleveland Steel, and will take orders for and maintain daily contact with each of the three companies."

SHEET METAL DATA SHEET 13

Manufacture of Tin Boxes

Compiled by J. W. Langton, M.B.E., B.Sc.(Lond.), M.I.Mech.E.

1. SEAMLESS BOXES (ROUND)

THE first division of these boxes is into circular and non-circular shapes, with ovals a mid-way case. Dependent on shape and size some ovals can be made on machines generally intended for circular boxes, some on that for non-circular. Seamless here refers to the fact that the bodies and lids are solid drawn *i.e.* have no side seam.

CIRCULAR SEAMLESS BOXES

Types

In practically all types the lid fits over the body, the amount or length of fitting being usually ended in a bead or shoulder but the shoulder is sometimes preferred because it gives an apparent "flush" finish. All dimensions are still arbitrary, but there is a B.S. Standard 1680 which says that the minimum amount of overlap of lid on body should be $\frac{1}{8}$ in. or $\frac{1}{16}$ diameter, whichever is the greater. The top of the lid shape can vary widely; the body usually has a sunken "bevelled off" recess. Normal variations in shape do not usually affect the manufacturing operations, but tin boxes like vacuum boxes need a little special consideration.

The bodies may be curled externally or internally, and the lids may be curled externally. Considerations are being made here all the time to the most common standard box types, as for boot polish and ointments. Special containers are not covered unless mention is specifically made.

Sizes and Substances

The maximum diameters seldom exceed $4\frac{1}{2}$ in. and depths seldom above $1\frac{1}{4}$ in. *i.e.* those requiring components which can be produced in the ordinary C-frame presses.

The usual tinplate substances used vary from about 0.008 to 0.0125, dependent on depths and diameters. Usually the lightest substance which will serve is chosen. For the deepest sizes deep-drawing-quality tinplate is usually advisable.

Body and Lid Diameters

The constancy of the final fit of lid to body depends of course on the establishment and maintenance of the relative two diameters. The original sizes as produced should be disturbed as little as possible in the subsequent rolling operations, but these operations are used to correct the effect of a number of inevitable variables, such as those of thickness variations and also physical variations of the tinplate itself, tool wear, etc. An empirical standard for the relative diameters of lid and body after pressing is that it should be possible to press the lid over the back of the body by hand, without exceptional difficulty. One suggestion, if the diameters are not right after final testing, is to adjust them in the cut and draw tools—never place any reliance on rolling as a serious corrective.

Basic Manufacturing Operations

The basic manufacturing operations for such containers with the *body untrimmed* and *uncurled* and the *lid uncurled* are:

(1) Cut sheets to size.
(2 Cut and draw the lid.
(3) Cut and draw the body.
(4) Roll body with bead or shoulder to establish lid fit.

The bodies are usually trimmed, when trimming is added to operation (4) simply by adding to the tooling.

Addition of Body External Curling

Here the body is not drawn straight cut, but is left with a small flange (of the order $\frac{7}{64}$ in. for medium-size boxes). If this flange is reasonably regular, it will not need trimming and the external curling can be combined in rolling operation (4) *i.e.* curling externally and beading and shouldering in the one operation. Then the only additional cost is the very small amount of the material for the flange, but in trimmed boxes this equates to the trimming allowance anyway.

Addition of Body Internal Curling

Here the operations now become:

(1) Cut sheets.
(2) Cut and draw the lid.

13 SHEET METAL DATA SHEET

Manufacture of Tin Boxes (Cont.)

(3) Cut and draw the body.
(4) Trim the body and start the curl.
(5) Pressure curl.
(6) Roll-on bead.

On small boxes it is possible to cut out the trimming and roll in the curl during the beading but the six operations given are more standard.

Lid-curling Addition

If the lid is to be curled then it is left with a small flange from the cut-and-draw die and this flange is rolled into a curl in a second operation. Alternatively the curl can be produced in a pressure curling tool, but curl rolling is usually faster, and gives a smaller size curl.

If the quantities are reasonably great, it is possible to cut, draw and curl in one operation in a more elaborate (and expensive) tool, provided the lid depths are not too great.

Plant Used

Taking the standard type first with uncurled lid, body trimmed, beaded and/or externally curled, the operations and basic plant would be :

(1) Cut sheets ... ... Guillotine or gang slitter
(2) Cut and draw lid ... ... Power press
(3) Cut and draw body ... ... Power press
(4) Roll (trim, bead external curl) ... ... Trimming and beading machine

Omitting considerations of cutting in this data sheet, the type of presses and trimmer and beader chosen or available determine the production outputs or *vice versa*.

The presses usually used are either (*a*) the standard inclinable ungeared taking cut strips fed to the tools by hand; or (*b*) special-purpose presses such as automatic strip-feed presses or sheet-fed presses.

The trimmers and beaders usually used are either (*a*) power machines where the work is fed to the tools by hand and removed by hand; or (*b*) power machines of the same automatic type where the work is fed down a feed chute to the machine, which feeds the bodies, carries out the work and removes the bodies afterwards. Here the bodies can be carried by a chute or conveyor from press to feed chute without the need of an operation.

In the production set-ups, various plant combinations are possible, and the outputs gained depend upon the quality of these combinations. Some rough approximations of the kind of outputs to be expected (*note* approximate) from a few plant combinations are as follows:

About 4,000 *to* 5,000 *per day*
One single-acting press
One simple-type trimmer and beader

About 8,000 *to* 10,000 *per day*
Two single-acting presses
One semi-auto. trimmer and beader.

About 10,000 *per day*
Special-purpose presses plus suitable number of semi-automatic trimmers and beaders.

A sheet-fed special-purpose press could give outputs of pressings of 30,000 a day.

On automatic strip feed presses, 150 to 300 per minute is possible.

Lid Curling

Here the same type of machine which trims and beads the body is usually used, so the one which gives the required kind of output is chosen.

Body Pressure Curling

The rotary operations are done in the same kind of trimmer and beader. The actual pressure curling operation is done in either (*a*) the usual single-acting power press using a pressure curling tool with a feed chute; or (*b*) a dial-feed press using the dial as a carrier.

The output from (*a*) in general terms can be approximately that of the cut-and-draw operation provided the feed chute, location of pressing and ejection are properly designed. The output from the dial-feed press, running at 70 r.p.m., can be 25,000 per day (2-in. diameter box).

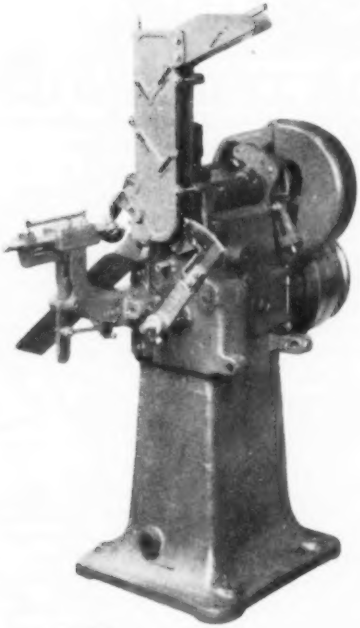
Plant Sizes

The single-acting presses used vary between 10 and 30 tons, which will cover the size range mentioned. They should be inclinable, but air cushions, while being useful and desirable, are not strictly necessary. The special-purpose presses are made to suit the purposes.

The trimmers and beaders have size capacities well over the sizes given, and are, of course, special purpose for their job.

SHEET METAL DATA SHEET 13

Manufacture of Tin Boxes (Cont.)



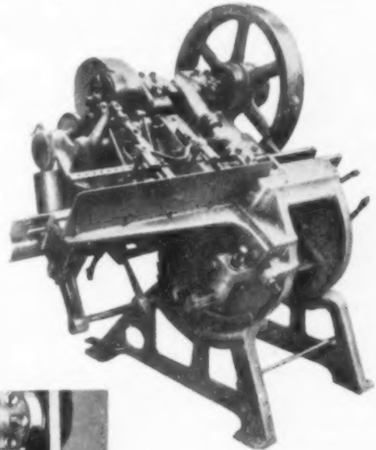


Fig. 1 (left).—Trimming and beading machine for circular seamless boxes

Fig. 2 (right).—Automatic strip feed press

Fig. 3 (below).—Press equipped with dial-feed attachment

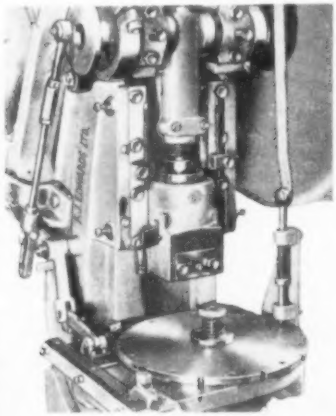


Fig. 6 (below).—Trimming and beading machine, hand fed

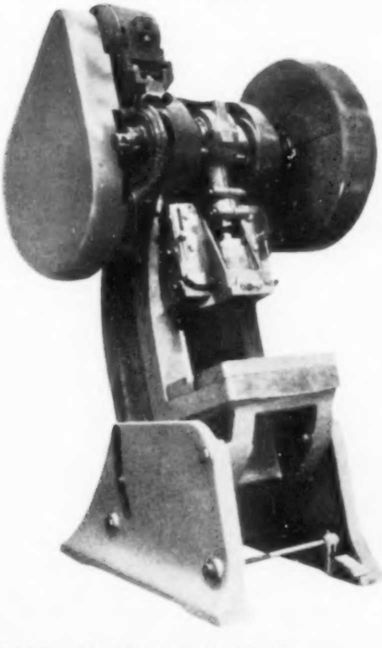
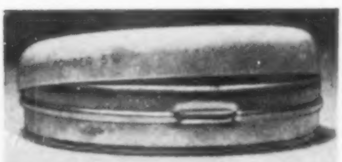
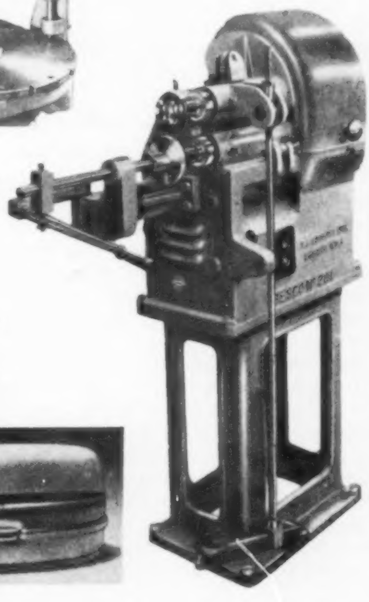


Fig. 4 (left).—Standard type C-frame inclinable press

Fig. 5 (below).—Showing external curling on body





INSTITUTE OF SHEET METAL ENGINEERING • *Review of Past and Forthcoming Activities*

COLD EXTRUSION OF STEEL
Plans for Future Work

THE drafting of the Technical Programme of the recent Conference on Cold Extrusion of Steel in Sheffield was the responsibility of a specialist sub-committee set up by the Technical Committee of the Institute to keep the subject under review and to recommend such action as it might consider desirable to promote technical development of the process. Following the Conference members of the Sub-Committee met to consider the significance of matters arising in the course of the discussion of the papers and to decide what recommendations should be made with regard to future action.

The Sub-Committee was unanimously of the opinion that there were still several aspects of the process which merited further investigation, and it is proposed to distribute a questionnaire to all those who were present at the Conference and to such other members of the Institute and others as might be interested in participating in a programme of co-ordinated work. It was envisaged that such subjects as tool life, the treatment and condition of billet material and the properties of extruded components are among those upon which further work could usefully be carried out.

Anyone who might be interested in participating in such work and would like to receive a copy of the questionnaire should communicate to that effect with the Hon. Secretary of the Institute at John Adam House, 17-19 John Adam Street, Adelphi, London, W.C.2.

PROGRAMME FOR 1961 CONFERENCE
Contributions Invited

The programme for the Annual Conference to be held in the late Autumn 1961 is now under active consideration by the Technical and Papers Committee and a certain number of offers of papers has already been accepted. In addition to the Sessions devoted to the general aspects of sheet metal engineering it is proposed to organize one session on the theme of "Problems Relating to Materials, Feeding, and Tooling in High-Speed Presswork Production." Offers of papers relating to this theme or to any other subject within the Institute's purview are invited and should be made at any early date. Any one desirous of submitting a paper to this Conference should communicate in the first instance with the Hon. Secretary of the Institute stating the proposed title of the paper and detailing briefly the manner in which the subject would be dealt with.

DEEP DRAWING RESEARCH

At the General Meeting of the International Deep Drawing Research Group held in Paris last May, the Founder chairman Dr. G. de Witte, vacated office at the end of his three-year term and was succeeded as chairman by Professor C. Crussard, Director of the Laboratories of the Institut de Recherches de la Siderurgie, St. German en Laye, France. At the same meeting the International Secretary, Dr. S. Garber (B.I.S.R.A.) intimated that his forthcoming appointment to a new position in Canada, would make it necessary for him to relinquish the position of Secretary during the course of the year. Dr. Garber's resignation became effective at the end of September last and Mr. John Hooper (Hon. Secretary of I.S.M.E.) was appointed Secretary in his stead. This International appointment entailed Mr. Hooper's resignation from the position of Secretary to the British Deep Drawing Research Group, and at the last meeting of the Group Committee Mr. Roger Pearce (Chief Metallurgist, Pressed Steel Co. Ltd.) undertook the responsibilities of Honorary Secretary to the British Group.

Other action taken by the Group Committee at this meeting included the setting up of three Panels devoted respectively to Materials, Processes and Methods of Tests. These Panels are currently in the process of meeting and drawing up their programmes of work in which the collaboration of a number of members active in this field has been invited.

NORTH-WEST BRANCH MEETING

At the meeting of the North-West Branch of the Institute held in Manchester, on November 30, the main lecture was preceded by a film made available by Henry Wiggin and Co. Ltd. on the subject of "Welding of High Nickel Alloys" which proved of particular interest to many of the members present who were engaged in utilizing these materials in aircraft construction. The principal part of the meeting was devoted to a lecture surveying some "New Methods of Chipless Machining" by Mr. A. P. Tuck (Hordern, Mason and Edwards Ltd.). In the course of this lecture, which was illustrated by a short film, the author dealt with the Hydroform, Hydrospin and Intraform processes and exhibited a number of samples of components produced by them.

The Branch has made arrangements to hold an additional meeting to those already announced. This is to be held on January 11 in Liverpool, at

(*Continued in page* 70)

SHEET METAL NEWS

FEATURING EVENTS AND PERSONALITIES IN THE INDUSTRY

STEEL COMPANY OF WALES PRODUCE V.L.N. (Very Low Nitrogen) STEEL

THE Steel Company of Wales Ltd. are using an oxygen/steam process to produce steel sheet with a nitrogen content as low as 0.0008 per cent, even less—in fact—than that of open-hearth steel.

It is well known that the quality of steel suitable for severe pressing or drawing operations must be of low nitrogen content, so that age-hardening effects while the material is in storage are reduced to a minimum. The normal Bessemer process of steelmaking using air blast or oxygen-enriched air blast cannot achieve this ideal because of pick-up by the steel of nitrogen derived from air. Later variations of the process have reduced the N_2 content of the normal Bessemer (0.016 to 0.018 per cent) to as low as 0.006 to 0.007 per cent, but even this figure is not low enough.

The Steel Co. of Wales process is unique because no air-blower is installed, so that it is quite impossible for nitrogen to be introduced into the blast. Other plants making steam/oxygen steel not only have air blowers installed, but also introduce air into the blast intentionally, in order to improve the furnace bottom and lining life, at the same time slightly raising the nitrogen content of the steel. The Steel Company of Wales, however, have now overcome the problem of furnace bottom and lining life *without using air*. The result is that, as had been theoretically anticipated, large quantities of S.C.W. oxygen/steam steel have now been used with complete success on the most difficult drawing operations known to the press shops.

The fact that the S.C.W. process of steam/oxygen steelmaking is primarily a user of molten pig-iron instead of scrap results in a very low content of "tramp elements" (nickel, copper, chrome and tin), which again contributes to the excellent ductility obtainable. Temperatures of the charge during blowing can be precisely and instantaneously controlled by adjustment of the steam/oxygen ratio—a further improvement which can only be controlled in other processes by more laborious methods such as, for instance, the addition of scrap in order to reduce the temperature.

At present three 50-ton converters are in use, each blowing 60 tons of steel, the weekly output being about 12,000 tons. A fourth converter is to be installed, so bringing the output up to about 18,500 tons per week. Although the process uses pig-iron the extra capacity to produce this is available, but experiments have shown that up to 15 per cent scrap can be used—without any adverse effect on the quality of steel produced, by altering the oxygen/steam ratio.

The steel is to be marketed under the name VLN (very low nitrogen) and the process is to be called the VLN process. It is interesting to note that the conversion costs using the process are lower than on the open-hearth process.

This is undoubtedly a major triumph for the British steel industry, and the material will have inestimable value to the press-working industry. No price premium will be put on this material, but it is to be hoped that all press-working firms, including the small firms, will be able to obtain adequate supplies.

THE SHEFFIELD SMELTING COMPANY LIMITED BI-CENTENARY CELEBRATIONS

THIS year the Sheffield Smelting Co. celebrated its 200th anniversary, and to commemorate the occasion made a presentation to each of the employees of the parent company and its subsidiaries. Over 600 people took part in the scheme and according to their length of service received gifts ranging from gold watches to radio sets.

The photograph shows Mr. R. Jardine, chairman of the company, presenting a tea service to Mr. E. G. Webb, Bullion Department Manager.

METAL PRINTERS RETURN TO OLD HOME AFTER 20 YEARS

THE old Imperial Works at Mitcham, which had been the head office and works of Hancock, Corfield and Waller Ltd. for nearly 40 years were destroyed by enemy aircraft in September, 1940, and since that time the company have been housed in the premises of two engineering companies of the group. Restrictions on building and capital expenditure in the early post-war years made it impossible to rebuild the factory to the standard required and later, as conditions improved, in view of the expansion of the company's interests and improved production methods, it was decided to design a modern plant. The old brick-built works have been replaced by a brick and steel framed structure equipped with the most modern and specialized plant for metal printing and production and all departments are again housed under one roof, ready and better equipped than ever to carry on with their operations.

The company started in 1891 when Mr. John Corfield, proprietor of a high-class tinsmith business, started to provide enamelled signs which were then becoming a popular feature of advertising; this was quickly extended by the establishment of connexions with brewers, distillers and mineral water manufacturers, leading to the production of patent caps for bottles. During the war years the firm transferred to the production of small metal parts for the services, including water bottles.

The original printing process involved individual drawing upon the stone for every printed design and this meant that almost as much detail was required to produce colourful plates and trays as a complete picture; the range of colours required was also enormous and as many as 19 individual printings were sometimes required to produce the effects which can now be produced with five. The first major change in production methods took place in the 1920's when it was found that rotary offset litho could be applied to the printing of metal in place of the flat-bed process and H.C.W. were among the first companies to produce photo-litho material by this process; the development of the silk screen process was an innovation of the late 1920's and led to the acquisition in 1957 of the firm of Bradley, Gale Ltd., silk screen printers and manufacturers of enamelled signs, who are now large-scale producers. Experience in other metal working techniques during the war period led also to the foundation of two major companies in the Corfield group—Corfield and Buckle Ltd., engineers, and Corfield-Sigg Ltd., manufacturers of "Crown Merton" holloware.

The new premises cover a total floor area of 60,000 sq. ft. and are designed to simplify the flow of work and minimize the handling of products. As much of the forming, pressing, cutting and shaping of the articles is carried out after the actual printing process, the printing machines are housed on the top floor and the work passes downwards to the press shops and then to the ground floor for storage, packing and despatch. The ground floors also accommodate the plant for Bradley, Gale Ltd.

The main printing units were installed by George Mann Ltd., and the high-speed rotary machines feed direct into C.H.A.L. automatic oil-fired ovens; varnishing and lacquering machines are harnessed to similar ovens, exceeding 105 ft. in length, the colours or lacquers being completely dried before emerging at the other end. The machines embody a considerable amount of automation, which not only reduces the degree of handling required, but also enable the printing and drying processes to be controlled with greater accuracy. The pressing and finishing shops contain over 100 power presses, cutting and curling machines, hand presses, bar folders, notchers, welders, spot welders, etc., for the production of shaped articles of all kinds, including waiters' trays, ash trays, embossed showcards, perpetual calendars, metal and wire dispensers, etc.

NEW MEDIUM SECTION MILL GOES INTO PRODUCTION IN BELGIUM

A MEDIUM section mill built by Schloemann Aktiengesellschaft, Düsseldorf, for the Société Métallurgique Hainaut-Sambre S.A. Couillet, Belgium, was recently put into operation. The new section mill is laid out to roll rounds, squares, flats, angles, channels and beams, in addition to parallel-flanged beams.

FOCUS ON WELDING EXHIBITION

A FULL range of arc-welding equipment, electrodes and accessories were displayed by the Welding Division of the English Electric Co. Ltd. at the "Focus on Welding" Exhibition held at the Kensington Court Sub-station on November 21 to 25. The main items of interest were the LWAD range of welding equipment giving a.c. or d.c. output at the turn of a switch and which is oil-cooled making it suitable for all climates, multi-operator sets with or without built-in power-factor correction capacitors which can be used by as many as 18 welders, a new meter for a.c. welding production, research and development which measures the electrical conditions in a welding arc and 26 different types of electrodes. The popularity of the exhibition, which also included welding demonstrations, has resulted in the English Electric deciding to hold the exhibition on show in its entirety from February 14 to 16, inclusive, at Bentley Bros. (Sheffield) Ltd., Saville Street Showrooms, The Wicker, Sheffield, 3.

"BEAGLE" GROUP ACQUIRES MILES AVIATION

BRITISH EXECUTIVE AND GENERAL AVIATION LTD. (BEAGLE) announce that arrangements have been agreed for the acquisition by the BEAGLE group of the aviation business of F. G. Miles Ltd., aircraft constructors of Shoreham Airport, Sussex. All the executive directors of F. G. Miles Ltd. will continue in their present posts. Mr. Peter G. Masefield and Mr. L. Blount will join the Miles board. Mr. Masefield will become chairman; Mr. F. G. Miles, deputy chairman; and Mr. J. W. P. Angell, general manager.

Mr. George H. Miles, already a director of the BEAGLE co-ordinating board, is to be appointed chief engineer of the BEAGLE group, which now comprises British Executive and General Aviation Ltd. with its two subsidiaries, Auster Aircraft Ltd. and the Miles aviation interests.

The arrangements now announced are the logical development of the manufacturing and technical liaison which has existed between BEAGLE and F. G. Miles Ltd. since the announcement of the new aircraft company.

The new arrangements, together with Rolls-Royce's intentions already announced, further consolidate and strengthen Britain's re-entry into world markets for light executive aircraft.

HEAVY STAMPING PRESSES NOW MANUFACTURED IN AUSTRALIA

THE manufacture of presses used in making motor-car bodies and other pressed steel items has become well established in Australia in the last few years and machines have already been supplied for the manufacture of Holden, Ford and Volkswagen cars.

The Melbourne firm of Vickers Ruwolt Pty. Ltd. has entered into an agreement for the manufacture of presses designed by the Clearing Machine Corporation of Chicago, which as a result of a recent merger is now known as The Clearing Division of U.S. Industries Incorporated, the Australian selling agent for whom is Max Chilton, Adelaide.

The presses now being produced in Australia are single- and double-acting units of 60 tons to 150 tons total weight, but Clearing presses of greater weight which are also usually included in motor-body stamping plants are still being imported from Great Britain where they are made by Vickers-Armstrong (Engineers) Ltd.

Vickers Ruwolt have installed new machine tools and other manufacturing facilities to enable them to produce larger and heavier presses than have previously been built in Australia. Part of their expansion programme includes the provision of a new electric furnace and a 50-ton travelling crane in the steel foundry in order to produce large castings to match the size of the machine tool equipment available for machining them. The amount expended on this expansion programme over the last three or four years exceeds £1 million of which the two floor boring machines represent approximately £250,000.

NEW PLATE LEVELLERS

FOLLOWING a contract for five heavy plate roller levellers for the new plate mills at South Durham Steel and Iron Co. Ltd., and Consett Iron Co. Ltd., The Head Wrightson Machine Co. Ltd., (a subsidiary of Head Wrightson and Co. Ltd.,) have received an order from Colvilles Ltd., for an 11-roll backed up roller leveller for dealing with hot steel plates up to 1 in. thick by 10 ft. 6 in. wide. Additionally a further order has been received from Consett Iron Co. for a second 9-roll backed up leveller capable of handling hot plates up to 1½ in. thick by 10 ft. 6 in. wide. The total value for contracts received recently for plate levellers for the steel industry amounts to approximately £550,000.

$3.5 MILLION FRENCH STEEL MILL

SOCIETE LORRAINE DE LAMINAGE CONTINU of France has signed a contract valued at over $3.5 million with International General Electric of New York and Societe Generale de Constructions Electriques et Mecaniques (ALSTHOM) to provide electrical equipment for one of the most modern and fastest tandem cold-rolling mills on the European continent. SOLLAC will instal the 6,000 ft. per min. mill at its Florange plant near Thionville, France, which is expected to be in commercial operation early in 1963. Under the contract, I.G.E. will supply main drive motors totalling some 24,000 h.p., the main drive control, X-ray gauges for continuous checking and automatic correction of steel thickness, and data logging equipment to record thickness as the steel is processed. In addition, I.G.E. will supervize the erection and have overall responsibility for the electrical equipment in the entire mill.

NEW WAREHOUSE FOR THE MIDLANDS

SAMUEL OSBORN AND CO. LTD., Sheffield, have opened a new Warehouse at 7 Millfields Road, Bilston, where stocks of tool steels, engineers' small tools and files are maintained for the convenience of customers in the Birmingham and Midlands area.

ELECTRIC RESISTANCE FURNACES

BRITISH FURNACES LTD. of Chesterfield, in association with Kepston Ltd., of Kinross, have formed a Kepston division of British Furnaces, for the production of electric resistance furnaces, to operate with controlled atmospheres, including hydrogen, nitrogen, argon, and helium, for heat treatment and brazing operations of most metals and stainless steels. The outstanding features of the Kepston furnace include complete absence of normal hydrogen hazards, controlled heating rates from very slow, up to 100° C. per min. to 1,600° C., controlled cooling from vacuum slow to 100° C. per min. down to 450° C., no restriction on size and shape of heating zone from laboratory size upwards, and operations under visual control at all temperatures.

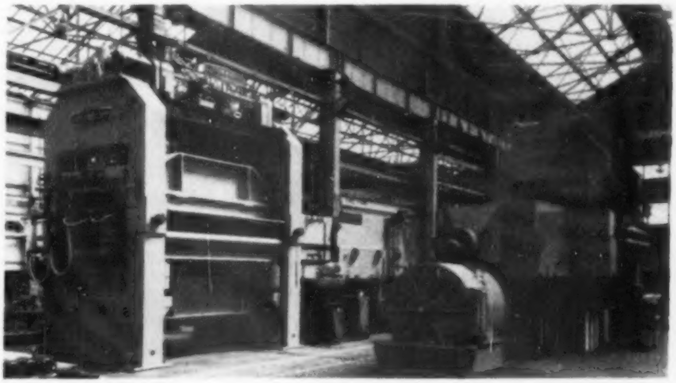
In addition to the foregoing, all electric resistance furnace enquiries will be handled by the Kepston division of British Furnaces Ltd., Derby Road, Chesterfield.

SHOCK ABSORBERS

ARMSTRONG PATENTS CO. LTD., manufacturers of automobile shock absorbers, use Desoutter power tools on their assembly lines, and a recent delivery included four identical bench mounted units each using six Desoutter type M.217 Screwdrivers mounted on the R.55.S. Stands.

PLATE LEVELLER CONTRACTS

LEFT, a 12-in. by 12½-in. by 138-in. 9-roll backed-up leveller for hot plates 1½in. thick by 10 ft. 6 in. wide; right, a 9-in. by 9-in. by 138-in. 11-roll backed up leveller for cold plates up to ¾ in. thick by 10 ft. 6 in. wide. Both machines have been supplied to the Consett Iron Co. Ltd. by The Head Wrightson Machine Co. Ltd.



APPOINTMENTS and STAFF CHANGES

Dr. Richard Waterhouse has been appointed managing director of **Acoustical Investigation and Research Organisation Ltd.,** known as AIRO, of 118, Cromwell Road, London, S.W.7, a member of the Hall-Thermotank group. Dr. Waterhouse received an M.A. from Magdalen College, Oxford, and a Ph.D. from the Catholic University of America, Washington, D.C. He has worked on research and development in acoustics for 16 years and his early technical experience included work on acoustic torpedoes for the British Admiralty and on a high intensity ultrasonic generator for experiments on pigment dispersion.

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Mr. Thomas A. Marshall, Jr., has been elected executive secretary of the **American Society for Testing Materials.** Mr. Marshall is currently senior assistant secretary of the Society of Mechanical Engineers and as executive secretary of ASTM will head a staff which supports a society of 10,500 members and 6,000 additional committee members. Mr. Fred F. Van Atta, formerly assistant secretary of ASTM, has been elected to the post of treasurer and Mr. Robert J. Painter, formerly executive secretary and treasurer, will continue as consultant to the executive secretary. Mr. Raymond E. Hess will continue as associate executive secretary, and as technical secretary and editor-in-chief is also responsible for the technical activities and publications of the society.

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Mr. M. Wade, formerly cost accountant, has been appointed works accountant of the **Barrow Steel Works Ltd.** and will be responsible to the secretary for the management and development of the works accounting service as well as development work on the work records service.

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The Consolidated Pneumatic Tool Co. Ltd. of 232, Dawes Road, London, S.W.6, have appointed Mr. Jack Gibson, B.A., LL.B. as managing director of their South African subsidiary, **The Consolidated Penumatic Tool Co., S.A. (Pty.), Ltd.,** Johannesburg.

Mr. E. H. S. van Someren has recently joined the **British Welding Research Association** as a principal scientific officer. He will be joining a team which includes mathematicians and metallurgists. Mr. van Someren was previously in the Research Department of Murex Welding Processes Ltd.; he is a Member of the Institute of Metals, and of the Institute of Welding, a Fellow of the Institute of Physics and Physical Society and an associate of the Royal Photographic Society.

* * *

Mr. J. F. Stammers, B.Sc., has succeeded Dr. J. C. Hudson, who has retired as head of the corrosion research in the chemistry department of **BISRA.** Mr. Stammers has acted as deputy for Dr. Hudson for the last eight years and represents the Association on the Technical Panel of the Joint Committee for the Co-ordination of the Cathodic Protection of Buried Structures.

Mr. E. E. White, F.R.I.C., A.M.I.M.M., F.Z.S., M.I.Inf.Sc., has been appointed head of the **BISRA** corrosion advice bureau. He was appointed technical secretary of the corrosion committees and chemistry department in 1950 and secretary of the newly-formed corrosion advice bureau in 1954.

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In recognition of their services to **W. P. Butterfield Ltd.,** Mr. C. Butterfield, chairman, has been elevated to life president and Mr. A. J. Butterfield, deputy chairman, has been made chairman. Both Mr. C. Butterfield, who is son of the founder, and Mr. A. J. Butterfield, a nephew of the founder, have given 50 years of service to the company.

* * *

Mr. C. R. Lappage, A.M.I-Prod.E., has been appointed technical manager of the **Drillmax** division at the Aldridge works of **Peter Brasshouse Ltd.** of Spring Hill, Birmingham 18. He will be assisted by Mr. R. D. Murphy, Mr. P. Leverton, and Mr. M. O'Connor, technical liaison engineers.

Mr. Arthur W. Williams, B.Sc., A.I.M., has been promoted chief technical representative of the sales service department of **James Booth Aluminium Ltd.** (Argyle Street Works, Birmingham).

* * *

Metal Industries Ltd. announce that Mr. D. L. Freeman has been made a director of **Cox and Danks Ltd.** and Mr. B. W. G. Gurney, who was previously works director of another M.I. company, John Allan and Co. (Glenpark) Ltd. has been appointed managing director of **Farmer Bros. (Shifnal) Ltd.** Mr. C. G. Abel has been appointed general sales manager of Farmer Bros.

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Following the death of Mr. A. E. Hollings, managing director of **Dowding and Mills Ltd.,** the industrial electrical repair specialists, Mr. G. A. Onions has been elected to the board and will act as director in charge of the Birmingham works; Mr. P. L. Hollings will continue as director controlling the London and Southampton works; Mr. W. L. Henderson is promoted to manager of the London works with Mr. P. A. Chambers as assistant, and Mr. H. Westwood is appointed manager of the Birmingham works with Mr. F. J. Gardiner as assistant.

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Mr. L. G. Whitworth has taken over the duties of press and public relations for the **Dexion Group** of Maygrove Road, London, N.W.6, manufacturers of slotted steel angle, open steel plank, etc.

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Gate Machinery announce that Mr. J. G. Fahey, Midland sales director and Mr. A. J. Cann, technical representative for South London and southern home counties of the Elgar Machine Co. Ltd., have joined the board of the company.

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J. A. Hemming Ltd., the bright steel strip stockholders of Birmingham and Oldbury, have appointed Mr. H. Warbrick, F.A.C.C.A., F.C.C.S., A.T.I.I., M.I.O.M., as their accountant.

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Mr. W. A. Attwood, M.A., A.M.I.Mech.E., M.I.H.V.E. has been appointed **H.M. Senior Engineering Inspector of Factories** in place of Mr. H. Eccles O.B.E., M.C., A.M.I.C.E., who retired recently.

(*Continued in page* 65)

Appointments and Staff Changes

(*Continued from page* 64)

Mr. G. H. Lowthian, M.B.E., has been elected chairman of the **Industrial Training Council** in succession to Lord McCorquodale who has been chairman since it was set up in July, 1958.

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Mr. Ernest Stanley Sellers, M.A. (Cantab), M.Sc. (London), M.I. Chem.E., who is head of the B.P. research centre, Sunbury on Thames, Middlesex, has accepted the invitation to be president of the **Junior Institution of Engineers** for 1960-1961.

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Mr. E. M. Thomas has been appointed resident representative in Hull of the machinery division of **George Cohen, Sons and Co. Ltd.**

* * *

Mr. J. F. Parker (chairman), Mr. G. St. J. Strutt, C.B.E., and Mr. E. S. Parker have retired from the board of **British Rolling Mills Ltd.** Mr. J. F. Parker was a founder director of the company, Mr. Strutt served as a director for 40 years and Mr. E. S. Parker has been connected with the company for nearly 50 years. Mr. R. Ll. Lloyd has been appointed chairman.

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Samuel Osborn and Co. Ltd. Sheffield, have made the following appointments to the boards of companies within the group.

Mr. A. Hutchinson, Mr. R. F. Horton, Mr. I. G. Buchan, to the board of **Samuel Osborn and Co. Ltd.,** Mr. J. Williams, Mr. V. P. Giles to be local directors and Mr. F. May to be chairman of the subsidiary board; Mr. R. Thompson to the board of **Burys and Co. Ltd.;** Mr. A. C. Dennis to the board of **Osborn Foundry and Engineering Co. Ltd.,** Mr. F. A. Kirk to the board of **Titanic Steel Co. Ltd.**

* * *

Mr. W. H. Parry has been elected president of the **Purchasing Officers' Association** for 1960-1961. He started his business career with Dugard Bros. Ltd., joined Wrights Ropes Ltd. of Birmingham in 1927, the purchasing department of Electrolux Ltd., Luton, in 1945 and three years later was appointed chief purchasing agent of Simplex Electric Ltd. of Oldbury. He joined the Charles Colston Group as purchasing manager two years ago and this year became general manager of the High Wycombe division.

Mr. W. B. Whitworth has been appointed sales manager of the Alloys Division of **Union Carbide Ltd.**

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Mr. Joel J. Shulman has been appointed Public Relations Manager to the **Pall Corporation,** Glen Cove, New York, and will be responsible for the public relations, technical sales literature, advertising and related activities. The Pall Corporation is considered to be the largest producer of stainless-steel filters in the U.S.A. and Pall filters are used in varied applications ranging from vehicles and jet aircraft to atomic submarines.

* * *

Further senior appointments to the production and engineering staffs of the Spencer works of **Richard Thomas and Baldwins Ltd.** now under construction at Llanwern, near Newport, Mon., include Mr. J. Fisher, hot mills manager, Mr. W. R. Harrison, blast furnace manager, Mr. R. L. Johns, B.Sc. (Eng.), A.M.I.Mech.E., chief mechanical engineer, Mr. L. T. Shore, steel plant manager, Mr. G. Short, assistant works manager, rolling mills, Mr. J. B. Thickens, chief metallurgist.

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Mr. R. Felgate has taken up the new post of sales executive (northern accounts) at the head office of **Rubery, Owen and Co. Ltd.,** Motor Division, Darlaston, Staffs., and Mr. R. Maxwell Sinclair, who has been appointed Motor Division European representative, will be responsible for all the Motor Division accounts in Europe.

* * *

Mr. C. E. Holmstrom, J.P., chairman of **Shepcote Lane Rolling Mills Ltd.** and a director of **Firth-Vickers Stainless Steels Ltd.,** has retired from the board of these two companies and is succeeded as chairman of Shepcote Lane Rolling Mills by Mr. J. T. W. Dewar, managing director of Firth-Vickers Stainless Steels Ltd. Mr. G. W. Ashton, general works manager, and Mr. J. Elliot, secretary and chief accountant, have both been appointed directors of Firth-Vickers Stainless Steels Ltd.

* * *

Tangyes Ltd., Cornwall Works, Smethwick, Birmingham, have appointed Mr. E. P. Bridson as sales manager of the home and export markets. Tangyes have built up a reputation for the supply of hydraulic equipment for high-tonnage lifting and handling tasks, which have included the lifting of the Jacques Cartier bridge in Montreal and the hydraulic driven tunnelling shield for Toronto subways and the Clyde Tunnel.

Mr. J. FISHER

Mr. J. B. THICKENS

Mr. Stanley Jessop has relinquished his appointment as sales manager of Fredk. Town and Sons Ltd., Halifax, and Woodhouse and Mitchell, Brighouse, both subsidiaries of **Thos. W. Ward Ltd.,** Albion Works, Sheffield, in order that he may take up special duties in connexion with the parent company's engineering activities in Scotland.

* * *

Mr. R. J. Abrahams has been announced as the sales director of the **Yale and Towne Manufacturing Co.'s** British Lock and Hardware Division at Willenhall.

* * *

Mr. H. A. Barratt, chief engineer of **Wallace and Tiernan Ltd.** of Chiswick, has been appointed to the board of **E.C.D. Ltd.,** Tonbridge, Kent, a subsidiary company specializing in pumping and air-conditioning equipment. The major part of the Chiswick works has been transferred to a new factory at Tonbridge and further expansions are now under way. Mr. Barratt still retains his post of chief engineer and will be largely concerned with supervising future expansions at Tonbridge.

TITANIUM IN NICKEL PLATING

OVER and above its use for steam heating coils, I.C.I. titanium is making another contribution to efficient and economic nickel plating in the provision of "non-consumable" hooks for supporting nickel anodes.

The cost of anode hooks represents a sizeable factor in the economics of nickel plating, their weight (between 4 and 8 oz.) is added in with that of the anode, so that they are paid for at virgin metal prices. Once used, they cannot be relied on for further satisfactory service, and the most the user can hope for is to recover the scrap value of the metal. The difference between buying and selling price corresponds to a loss of at least 1s. a hook. In addition the plating solution which dissolves the anode has a similar effect on a hook of the same metal and for this reason, some form of protective sheathing of the hook is necessary. It is also usual to work with the hook, and often the top inch or so of the anode too, above the surface of the solution, which not only presents technical disadvantages but also means that the anode is incompletely used.

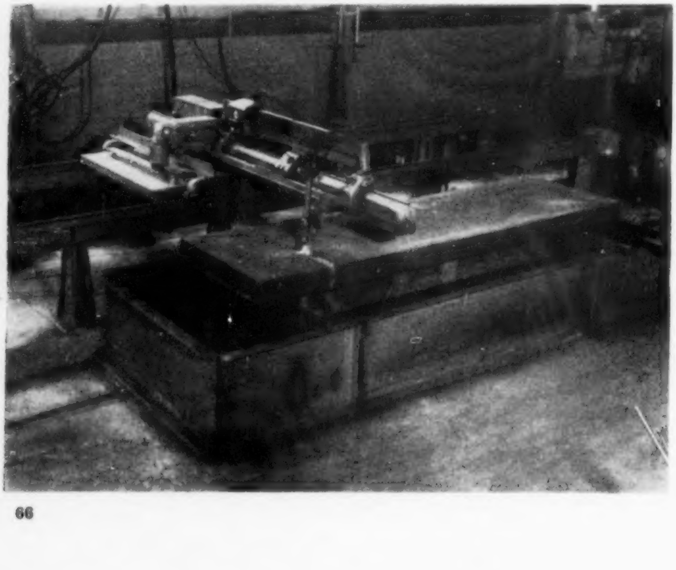
Hooks made of titanium are so impervious to attack by nickel plating solutions that they can be used as permanent fixtures; they are screwed into the anode in the normal way and transferred from each finished anode to the next one. Titanium hooks installed early in 1958 are still in service and apart from wear on the thread, which does not affect performance, they are in perfect condition and are expected to last at least as long again.

Titanium is completely resistant to all commonly-used dull and bright nickel plating solutions and consequently, the hook can be taken right down into the solution, so that the whole surface of the anode is in contact with the plating solution.

Laboratory tests over many months by a manufacturer of nickel anodes show that there is no preferential dissolution of the nickel near the thread. This confirms the experience of platers, who find that fully immersed anodes wear more evenly and can be used more completely.

POWDER CUTTING WITHOUT FUMES

POWDER cutting without fumes has been made possible by fitting a fan-extractor trough below a British Oxygen Bison Mark II profile cutting machine, at Shepcote Lane Rolling Mills Ltd., Sheffield. The fumes are fan-extracted through a trough which is let into the concrete floor below the cutting bench and vented into the atmosphere outside the building. The trough is fitted with three ports which can be opened or closed depending upon the direction of the cut. This ensures maximum extraction where the fumes are most concentrated. At the mills about one ton of iron powder is used each week in preparing the stainless-steel slabs which are 10 ft. long, $3\frac{1}{2}$ ft. wide and weigh up to 8,000 lb.



BRITISH COMPANY TO MANUFACTURE TITANIUM OXIDE IN U.S.A.

THE formation of a joint company to manufacture titanium oxide in the United States is announced jointly by Laporte Industries Ltd. and American Potash and Chemical Corporation of Los Angeles.

The plant will be situated in California and will be the first to be built in the West Coast area. The share capital will be divided in the proportion of American Potash 85 per cent and Laporte 15 per cent. Technical information and plant design will be supplied by Laporte Titanium Ltd. and based on this information, American Potash will construct the plant and operate the new business.

Initial capacity will be 25,000 tons per annum at an estimated capital expenditure of $15,000,000. Suitable provision for further expansion will be made. The plant is expected to come into production in the latter part of 1962.

NEW PROCESS REDUCES HEAT TREATMENT TIME

AN entirely new design of heat transfer equipment that can cut the heating time of metals by 85 per cent is incorporated in a line of batch furnaces for heating beds, quenching beds and work handling equipment available from International General Electric of New York Ltd., the international marketing organization of U.S. General Electric. The new system is called a "fluidized bed". It heats parts in a dense dispersion of hot, highly turbulent solid particles suspended by a controlled stream of air or other gases. These particles have virtually the same physical (and thermal) properties as a true liquid, but they are inert and will not wet, abrade or otherwise affect the equipment or work. The fluidized bed process may be used in annealing, normalizing, solutionizing, ageing, hardening and isothermal transforming. The time saved in the processes is also a monetary saving, since furnace capacities are made greater.

The fluidized bed permits heat transfer co-efficients of 70 to 130 B.Th.U. per hr. per sq. ft. per degree Fahrenheit between the particle bed and the work; and provides intermediate quenching rates. These rates can be varied, permitting selection of quenching rates between those of oil and air.

OVER £3½ MILLION ROLLING MILL FOR NEW ZEALAND

PACIFIC STEEL LTD., New Zealand, announces that an agreement has now been signed to provide the finance for the new steel rolling mill which it is building in Auckland, New Zealand. The total cost of the project is estimated at £3,600,000. £1,650,000 will be provided in the form of equity capital of which 60 per cent will be held by a New Zealand group, led by Fletcher Holdings Ltd., and 40 per cent in equal amounts by Colvilles Ltd., Guest, Keen and Nettlefolds Ltd., and Stewarts and Lloyds Ltd. £1,100,000 is being provided in the form of Debenture Stock placed by Lazard Brothers and Co. Ltd., with The Commonwealth Development Finance Co. Ltd., fifteen United Kingdom insurance companies and The South British Insurance Co. Ltd. of New Zealand. The balance of £850,000 will be provided in the form of short and medium term loans respectively by the Bank of New Zealand and The National Bank of New Zealand Ltd.

The mill will have an initial capacity of 50,000 tons of rolled bar products per annum and the steel will be produced using scrap collected in New Zealand.

HEATING INSTALLATION FOR GERMANY

THE Loewy Engineering Co. Ltd., Bournemouth, has received through Mannesmann Export GmbH, an order for the supply of a mains frequency induction heating installation for steel billets. The equipment will be installed at Mannesmann A.G., Roehrenwerk, Remscheid, Germany. The value of the order is over a quarter of a million pounds.

The equipment to be supplied is for a nominal capacity of 21 tons per hour, with provision to increase the output later to 28 tons per hour. It will have a power rating in excess of 10 megawatts, and is believed to be the largest induction heating installation in the world ordered for a steel extrusion plant.

The billet heating equipment is for a Loewy 3100 tons hydraulic extrusion press plant for steel, of new design, which is at present under manufacture.

TONNAGE OXYGEN PLANT FOR MIDLANDS

TONNAGE oxygen is to be provided to the Rotherham works of Steel, Peech and Tozer by The British Oxygen Co. Ltd. to meet the requirements of the company's new electric arc furnaces to be installed in the Templeborough melting shop under their current development programme. B.O.C. are already extending the liquid oxygen manufacturing plant at their Brinsworth works and to meet this new demand they will now add a 100-tons per day tonnage oxygen plant at Brinsworth. The oxygen will be piped from Brinsworth to Steel, Peech and Tozer's Rotherham works which are about half-a-mile away. The installation of this large plant will provide cheaper oxygen gas in the heart of the Sheffield/Rotherham area and brings the time nearer when pipeline supplies can be made available to other major users in this important industrial area.

RESISTANCE WELDING CONTROL EQUIPMENT—PRICE REDUCTIONS

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LTD., Rugeley, Staffs, have recently made price reductions to their range of comprehensive resistance welding controls, Series CRW.1. The reductions, which average 10 per cent on previous list prices, have been made possible by rapidly increasing production and improved methods of manufacture of this versatile equipment.

The Series CRW.1 provides a range of 42 different types of equipment in a common basic cubicle assembly including installations for synchronous spot, seam, pulsation (or "woodpecker") welding. The standard sub-units which make up the various types of installation employ printed circuit techniques with plug and socket interconnexions to simplify maintenance.

PLASTIC BONDED ALUMINIUM FOR NUCLEAR SUBMARINE

THIS "Warerite" aluminium being inspected at Bakelite's Warerite factory at Ware, is part of a large order of over 11,000 sq. ft. which has been shipped recently to Vickers-Armstrong yard at Barrow-in-Furness for installation in the Dreadnought, Britain's nuclear submarine. The material consists of decorative laminated plastics bonded by a special process to an aluminium core of 6, 8 and 10 gauge, which will be used for false bulkheads or as panelling for steel bulkheads. It is easy to keep clean, impermeable, splinter-proof and of great strength.

The whole of the structure above the strength deck in the liner "Oriana" is made of aluminium. It is made up of about 1,000 tons of plate and sections of which Alcan Industries Ltd. (then Northern Aluminium Co.) supplied some 900 tons.

PROTECTIVE COATING OF HEAVY EQUIPMENT

A NEW service for the application of a comprehensive range of anti-corrosion and protective coatings to heavy equipment up to 5 tons in weight has been established at the works of West's-Loyne Ltd., Norton Street, Miles Platting, Manchester, by the installation of specialized plant, which includes one of the largest fully automatic shot-blast cabinets installed in Britain for this kind of work, and a large gas-fired oven for the sintering and stoving of coatings or the heat treatment of metals. The installation is complete with up-to-date preparation and coating equipment and the necessary cranes for the moving of large items while under treatment.

Among the coatings applied are epoxy resins for the linings of vessels containing food, oil or chemicals, phenolics (water and acid resistant), synthetic rubber for abrasion resistance and corrosion prevention, P.T.F.E., P.T.F.C.E. for insulation and resistance to high temperature and corrosive gases and acids, silicones, metal spraying (zinc, aluminium and stainless steel), and flame spraying (polythene, nylon, P.V.C.).

The gas-fired oven is 30 ft. long, 12 ft. wide and 10 ft. high and is designed for sintering P.T.F.E. and P.T.F.C.E. and for stoving high-bake epoxy, phenolic and silicone coatings. A temperature of 450° C. can be attained when needed for heat treatment of metal if required before P.T.F.E. coating. Provision is also made for curing coatings by hot air and infra-red heaters. Other facilities available at the plant include equipment for shot blasting very large vessels in the open with mineral grit and preparation by flame cleaning and power wire brushing. Both powder and wire metal spray guns are used for flame spraying zinc, aluminium and stainless steel as well as for the synthetic coatings. Pipes and ducting can be internally coated by spray or flow coating. Other types of application are by spray, brush and trowel.

West's-Loyne Ltd. is a company recently jointly formed by W.G.I. Ltd. (West's Group of Industries), engineers, of Manchester, and Loyne Ltd., protective coating specialists of Ashton-under-Lyne, and will be able to draw upon the engineering experience of the Group companies which operate in a number of different fields.

AMERICAN COMPANY TO MANUFACTURE STRIP AND TIN MILL EQUIPMENT IN GREAT BRITAIN

THE Wean Engineering Co., Inc., of Warren, Ohio, has established a new company in Great Britain—Wean-Miles Ltd. of 76, Cannon Street, London, E.C.4—to manufacture and sell strip and tin mill equipment in Great Britain of Wean design. The British company will maintain the Wean Engineering Co's. design at all times and will adapt Wean (U.S.A.) drawings to British standards; in case of spare parts intended to replace American parts, the Wean designs will be strictly adhered to in order to ensure absolute interchangeability.

The Wean Engineering Co., working through Wean-Miles Ltd. has equipment under construction for the British steel industry, including one high-speed electrolytic tinning line, two continuous strip pickling lines, two high-speed shear lines, one high production continuous strip annealing line for tinplate and a slitting line.

Officers of Wean-Miles are:—R. J. Wean and John Miles, co-chairmen; R. J. Wean, Jr., alternate co-chairman; D. A. McArthur, managing director; J. R. Thring, director and secretary; A. R. Geiszler, deputy managing director; and C. Frenkel, retained as consultant.

VENESTA ACQUIRE ACORN ANODIZING CO.

THE directors of Venesta Ltd. recently announced that they had acquired an 80 per cent interest in Acorn Anodizing Co. Ltd., leading jobbing anodizers and metal finishers in London and Birmingham. Acorn Anodizing Co. Ltd. will continue their present activities and will also co-operate with two other subsidiaries of Venesta Ltd., namely Venesta Plywood Ltd. and Venesta Metal Containers Ltd. in the development of projects which are complementary to these companies.

The management of Acorn Anodizing Co. Ltd. remains unchanged.

WICKMAN ASSUME AGENCY FOR ELERODA ELECTRO-EROSION MACHINE

WICKMAN LTD. announce that under an agreement recently concluded with Ateliers des Charmilles, S.A., Geneva, they have assumed the sole selling agency in the United Kingdom for the Eleroda Model D.1. Electro-Erosion machine.

The Eleroda machine is already well known in this country as a high-precision spark machining unit particularly designed for tool-room application, and its addition to the Wickman range will complement the present range of erodomatics manufactured by the company.

AUTOMATIC shot-blasting cabinet at West's-Loyne Ltd. Miles Platting Manchester to accommodate work up to 30 ft. × 12 ft. × 12 ft.

Forthcoming Events . . .

January 4

Institute of Metals (Leeds Metallurgical Society). "Some Recent Developments in the Welding of Metals," by E. N. Gregory, at the Bradford Institute of Technology. 6.30 p.m.

The Newcomen Society. "Joshua Gilpin, an American Manufacturer in England and Wales, Part II, 1811-1814," by Dr. Harold B. Hancock and Dr. Norman B. Wilkinson, at the Science Museum, Kensington, London, S.W.7. 5.30 p.m.

January 11

North Wales Metallurgical Society. "Steelmaking for Flat Rolled Products," by R. Mayorcas, B.Sc. (John Summers and Sons Ltd.), in the Lecture Theatre, Flintshire Technical College, Connahs Quay, nr. Chester. 7.0 p.m.

Institute of Sheet Metal Engineering (Midland Branch). Forum; "Tooling for Short Run Production," in the Midland Hotel, Birmingham. 6.45 p.m.

Institute of Metals (Manchester Metallurgical Society). "Modern Methods of Metallurgical Analysis," by K. M. Bills, at the Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

January 12

Institute of Metals (Metal Physics Committee). "Metallurgical Research at High Pressures," at the Institute of Metals, 17 Belgrave Square, London, S.W.1. 6.30 p.m.

January 16

Sheffield Society of Engineers and Metallurgists. Symposium on "Casting *versus* Welding." Speakers: for welding, Dr. R. Weck, B.W.R.A.; for casting, A. H. Sully, B.S.C.R.A. Visitors welcome at this meeting, which will be held at the University, Sheffield. 7 p.m.

January 18

Society of Chemical Industry (London Branch). "Metallic Diffusion Coatings," by R. L. Samuel, at 14 Belgrave Square, London, S.W.1. 6.0 p.m.

January 25

Institute of Sheet Metal Engineering (Wolverhampton Section). Lecture "Panel Dies," in the Wolverhampton and Staffordshire College of Technology, Wulfruna Street. 6.45 p.m.

January 26

Institute of Metals (Southampton Metallurgical Society). "Hot Dip Galvanizing," by M. H. Davis, B.Sc., at Southampton University. 7.15 p.m.

January 30

Institution of Plant Engineers (West and East Yorkshire). "The Uses of Molybdenum Disulphide," by G. J. Vineall, B.Sc., F.R.I.C., F.Inst. Pet. (Rocol Ltd.), in the Houldsworth School of Applied Science, Leeds University.

January 31

Institute of Sheet Metal Engineering (South-West Branch). Forum "The Applications of Aluminium," in the Small Lecture Theatre, Engineering Laboratories, University of Bristol. 7.0 p.m.

BIRMINGHAM METALLURGICAL SOCIETY

A STUDENTS' evening has been arranged by the Birmingham Metallurgical Society to take place at the College of Advanced Technology, Gosta Green on February 2 and will be open to all students who are studying at a college in Warwickshire, Worcestershire or South Staffordshire, who are not more than 25 years of age to exhibit their ideas competitively. Ideas can be devices, illustrations, constructions or layouts of a metallurgical nature. Particulars of entries should be sent to the secretary of the Birmingham Metallurgical Society, c/o Brown Bayley Steels Ltd., 21 Bennett's Hill, Birmingham, 2.

INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY ANNUAL EXHIBITION

AS a result of the recent amalgamation of The Institute of Physics and The Physical Society, The Physical Society Exhibition of Scientific Instruments and Apparatus will be known as The Annual Exhibition of The Institute of Physics and The Physical Society and will be held at the Royal Horticultural Society's Old and New Halls, Westminster, London, S.W.1, from January 16 to 20. Demonstration lectures will be given on "Hydrodynamic Research," "The Physics of the Oceans" and "Some Physical Problems in Travelling at Supersonic Speed." Tickets are available from the Institute of Physics and The Physical Society, 47, Belgrave Square, London, S.W.1.

SYMPOSIUM ON LIGHT METAL INDUSTRY IN INDIA

THE National Metallurgical Laboratory, Jamshedpur 7, India, are to hold a symposium on "Light Metal Industry in India" in the Auditorium of the National Metallurgical Laboratory, Jamshedpur, from February 14 to 17, 1961. Professor M. S. Thacker, director-general, Scientific Research, New Delhi, will inaugurate the symposium on February 14, at 10.30 a.m. Sir J. J. Ghandy, Kt. G.I.E., director-in-charge, The Tata Iron and Steel Co. Ltd. and chairman of the executive council, National Metallurgical Laboratory, will preside. A large number of scientific and technical contributions dealing with different aspects of the light metals industry have been received for presentation from leading metallurgists and scientists both in India and elsewhere.

SYMPOSIUM ON BETTER DESIGN OF PRESSURE VESSELS

THE Institution of Mechanical Engineers is arranging a Symposium on "Pressure Vessel Research towards Better Design" to be held at the Institution on January 18-19, 1961.

The arrangements are being made by a Committee under the Chairmanship of Mr. H. N. Pemberton. The papers, about 12 in number, will be divided into contributions dealing with components and experimental research, and those considering design and design codes.

The provisional programme is: January 18, 1961: Session 1, 2.30 p.m.-5.00 p.m. Reception; 7.00 p.m. for 7.30 p.m.

January 19, 1961: Session 2, 10.00 a.m.-12.30 p.m.; Buffet Luncheon, 12.30 p.m.-2.30 p.m.

Session 3, 2.30 p.m.-4.30 p.m.; Tea, 4.30 p.m.-5.30 p.m.; Session 4, 5.30 p.m.-7.30 p.m.

Concessional charges for registration and papers are available to members of The Institute of Refrigeration, The Institute of Welding, The Institution of Chemical Engineers, The Institution of Electrical Engineers, The Institution of Mechanical Engineers, and The Iron and Steel Institute.

Full particulars may be obtained from the Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

Cold Extrusion of Steel

(*Continued from page* 7)

more interest in the field of forging rather than as a preliminary to more normal presswork operations and it was with this aspect of the situation in mind that the Institute invited the collaboration and participation in the Conference of the National Association of Drop Forgers and Stampers, an invitation which resulted in that Association being strongly represented among the delegates of the Conference.

The selection of Sheffield as the venue for the Conference stemmed from the belief that the ultimate general adoption of the process into the production scene must depend very largely on the availability of billet material of adequate quality and also on the ability of the tools to stand up for economically long periods to the very substantial stresses to which they are subjected during the extrusion operation. The fact that this belief was well founded emerged clearly from the discussion, a great deal of which was centred around these two aspects of the subject.

The technical organization of this Conference was the responsibility of a special committee appointed by the Technical Committee of the Institute whose personnel comprises representatives of most of the organizations which have been carrying out work on the process in this country. This committee has under review a number of subjects relating to the wider application of the cold extrusion process and is proposing to initiate a programme of co-operative investigation in which its own members will participate. In the belief that there may be other companies and organizations who would be interested in participating in this work, an invitation is to be sent out to all those who attended the Conference asking them for their active co-operation and for their suggestions as to the channels in which future work on the process could be directed. The committee hopes to be able to report on progress and developments from time to time.

Institute of Sheet Metal Engineering

(*Continued from page* 60)

which it is hoped many members will be present who find it difficult to attend regularly meetings held in Manchester. Anyone in the Liverpool area who would like to receive details of this meeting is invited to communicate with the Hon. Secretary of the North-West Branch, Mr. J. H. Rose, Hordern, Mason and EdwardsLtd., St. John's Chambers, 2, St. John's Street, Deansgate, Deansgate, Manchester, 3.

RÉSUMÉS DES PRINCIPAUX ARTICLES

Materiaux pour Outils à Emboutir page 43

A. G. Shaw

Dans cet article l'auteur traite des matériaux d'outillage sous les rubriques suivantes:—résines époxyde, alliages à base de zinc, bronzes d'aluminium et aciers à outils. Il examine le développement de chacun de ces matériaux et donne des comparaisons de prix de revient, ainsi que certains renseignements sur les problèmes de lubrification qui se présentent au cours de l'emboutissage: il mentionne, par exemple, le procédé "Sulphinuz," le phosphatage, la nitruration, le placage au chrome dur, etc. Il propose également une suite de règles fondamentales pour mener à bonne fin l'utilisation des aciers à outils dans l'étirage, profond et l'emboutissage.

Introduction à la Théorie et à la Pratique du Laminage de Tôles Planes .. .. page 49

C. W. Starling, B.Eng., A.M.I.Mech.E. (*décédé*)

Voici le cinquième chapitre du livre du regretté C. W. Starling, écrit spécialement dans le but d'expliquer clairement la pratique et la théorie du laminage à l'ouvrier lamineur. Dans ce chapitre l'auteur considère principalement les forces agissant sur la cage du laminoir. Il examine le problème du point de vue du type de cage conventionnelle, de la cage à cale boulonnée, de la cage précontrainte et du train articulé (conçu par l'auteur). Il traite également dans ce chapitre de la courbe d'élasticité du laminoir et de la méthode par laquelle elle s'obtient. Après avoir paru en feuilleton dans "Sheet Metal Industries," ce livre sera publié par la University of London Press.

ZUSAMMENFASSUNGEN DER HAUPTARTIKEL

lung der einzelnen Stoffe wird beschrieben und ein Preisvergleich angestellt. Auch zum Problem der Schmierung beim Pressen werden einige Angaben gemacht, es werden z.B. das Sulphinusverfahren, Phosphatieren, Nitrieren, Hartverchromen usw. erwähnt. Weiter wird eine Reihe von Grundregeln für die erfolgreiche Anwendung von Werkzeugstählen beim Tiefziehen und Pressen aufgestellt.

Einführung in die Theorie und Praxis des Blechwalzens—5 .. .. .. Seite 49

C. W. Starling, B.Eng., A.M.I.Mech.E.

Dies ist das fünfte Kapitel des Buches, das der verstorbene Verfasser mit dem ausgesprochenen Ziel schrieb, dem Walzwerksmann die Theorie und Praxis des Walzens in leichtverständlicher Form nahezubringen. Das vorliegende Kapitel beschäftigt sich hauptsächlich mit den auf den Walzenständer wirkenden Kräften und der Verfasser behandelt im einzelnen den gewöhnlichen Ständer, den Ständer mit verschraubtem Einbaustück, den vorgespannten Ständer und das von ihm selbst konstruierte Gelenkwalzwerk. Das Kapitel beschäftigt sich weiter mit der Biegelinie eines Walzwerkes und dem Verfahren zu ihrer Bestimmung. Das zuerst in Fortsetzungen in der Zeitschrift „Sheet Metal Industries" erschienene Werk wird von der University of London Press herausgegeben.

NEW PLANT and EQUIPMENT

A monthly review of new machines, equipment, processes, etc., of interest to the producer and user of sheet metal

Pneumatic Air Thruster

P. L. WILLCOX LTD., Standard Works, Tyseley, Birmingham, 11, have produced a range of pneumatic thrusters (or dosers) which enable a thrust of over 2½ tons to be obtained from air lines of 80/90 lb. per sq. in. and are suitable for installation on lines of manufacture for bending, holding, punching, pushing, lifting and gripping. The models are fitted with a diaphragm and have a stroke varying between 1.181 in. and 1.968 in. but by using a lever arm, this movement can be increased; the principle of operation is that the air pressure is transmitted by the diaphragm acting on a piston and rod to smaller dimensions causing a downward thrust of greater power; the diaphragm is returned to its normal position on the release of the air pressure by means of a return spring. Dosers with a maximum pressure power of 660 lb. at a positive air line pressure of six atmospheres are also produced with a cylindrical case and a longer stroke than the diaphragm model.

Trip Hammers

FIG. 1 illustrates a trip hammer manufactured and marketed by Arnott and Harrison Ltd., 22 Hythe Road, Willesden, London, N.W.10, who have been producing equipment for various finishing and assembly operations, including presses and dial printing machines for several years. The trip hammer, which has been redesigned recently to embody a number of additional features, is basically a light double-action press and can be used for staking, heading, riveting and also light piercing operations. The main ram is comprised of an outer sleeve, an inner sleeve, which is loaded by an internal spring, and a rod which is a loose fit in the bore of the inner sleeve; the outer sleeve is a carrier for these parts and in operation descends towards the work piece mounted on the base and then the inner sleeve which acts as a pressure pad, grips the component pieces which may be required to be riveted tightly together; on further movement of the ram, a trip is actuated releasing the punch rod which has been pressurised to give a hammer action. The standard blow of the hammer is 800 lb. but this can be adjusted by removing the top cover and repositioning one spring fixing. The column can be adjusted vertically from the base to give a range of working conditions; slots are provided in the base for fixing to a bench and a treadle is also supplied for foot operation thereby leaving both hands of the operator free for ease of working. Pneumatic operation can also be fitted if required.

Fig. 1.—Trip hammer

High-capacity Lightweight Air Compressor

AN air compressor designed specially for small workshop and foundry is being manufactured by Atlas Copco (Great Britain) Ltd. of Maylands Avenue, Hemel Hempstead, Herts. The compressor, catalogue number TT6, is a two-stage, single-acting machine with an intercooler built for a normal working pressure of 100 lb. per sq. in. and a free air delivery of 140 cu. ft. per min. and is complete with a flange-mounted electric motor. The complete power-pack unit weighs only 1,050 lb. and is mounted on rubber feet which eliminate foundation costs and enable it to be placed on concrete floors wherever it is needed.

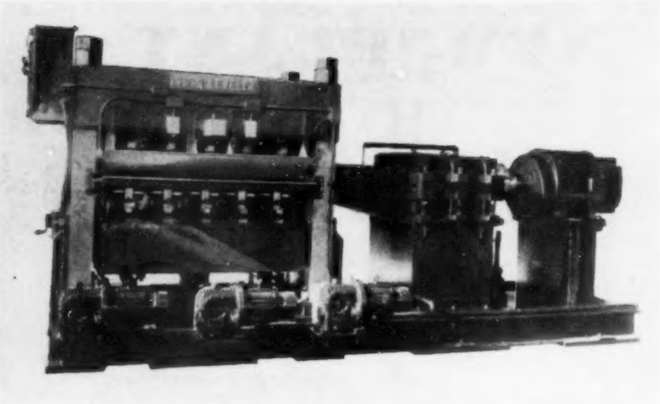


Fig. 2.—High-speed levelling machine with spring-loaded spindle drive

Levelling Machine

FIG. 2 shows one of a range of roller levelling machines produced by the Voss Engineering Co. of Pittsburgh, U.S.A., for whom the agents in this country are Gaston E. Marbaix, Ltd., Devonshire House, Vicarage Crescent, London, S.W.11. These machines are used by many of the foremost steel companies in America and are claimed to incorporate a method of flattening which is superior to other levelling procedures.

The Voss roller leveller is constructed of two major group assemblies consisting of a top frame and a bottom frame that carry the works rolls and all of the major levelling mechanisms; these group assemblies can be taken down in a matter of a few minutes by removing the four corner-bolt nuts and removing the top frame to an accessible location, thus facilitating maintenance. Basically the leveller relies on a set of long slender work rolls, supported by a back-up roller mechanism, to flatten the material passing between them. Simultaneous adjustment of the upper back-up roller flights allows localized pressure, during operation, to be increased or decreased for light or heavy sheet centres or buckles; individual adjustment of lower flights for added localized pressures can be made manually by a crank mechanism during operation. An ingenious spindle drive is incorporated, which is spring-loaded and self-adjusting in length to angular position which facilities maintenance when work roll change becomes necessary. The leveller flattens at high speed to stretcher leveller flatness.

One-way Photo-electric Cell

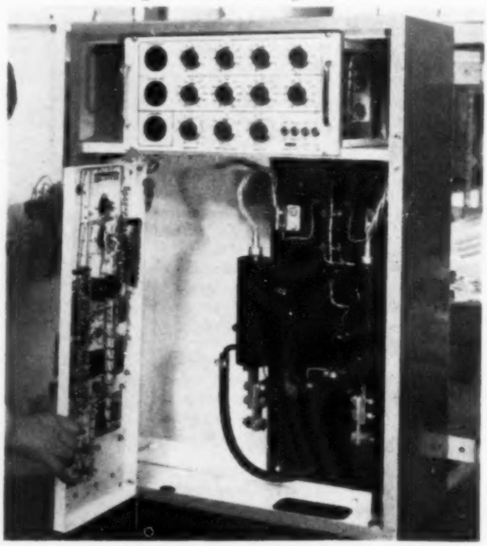
A PHOTO-ELECTRIC cell unit that will operate only when the light beam is interrupted in one direction is being produced by Hird-Brown Ltd. of 244 Marsland Road, Sale, Cheshire, who have also introduced a photo-electric cell warning system for giving audible or visible alarm in which the new technique can be incorporated. The five basic components of the warning system are the control unit, with its watertight cover removed, the transformer, the projector, the receiver and the three-inch diameter bell. The cell is such that if an object passes through the beam in the reverse direction, nothing will happen. The warning system can be used to monitor moving webs of any material and immediately indicates when a break or tear occurs and several beams can be connected to one control unit. The warning can be set on site to sound continuously or to stop ringing after five to 15 seconds and the equipment is suitable for beam lengths of up to 75 ft. and for operation indoors or outside under wide temperature variation and under sm oky conditions.

Electronic Gun-welding Control Equipment

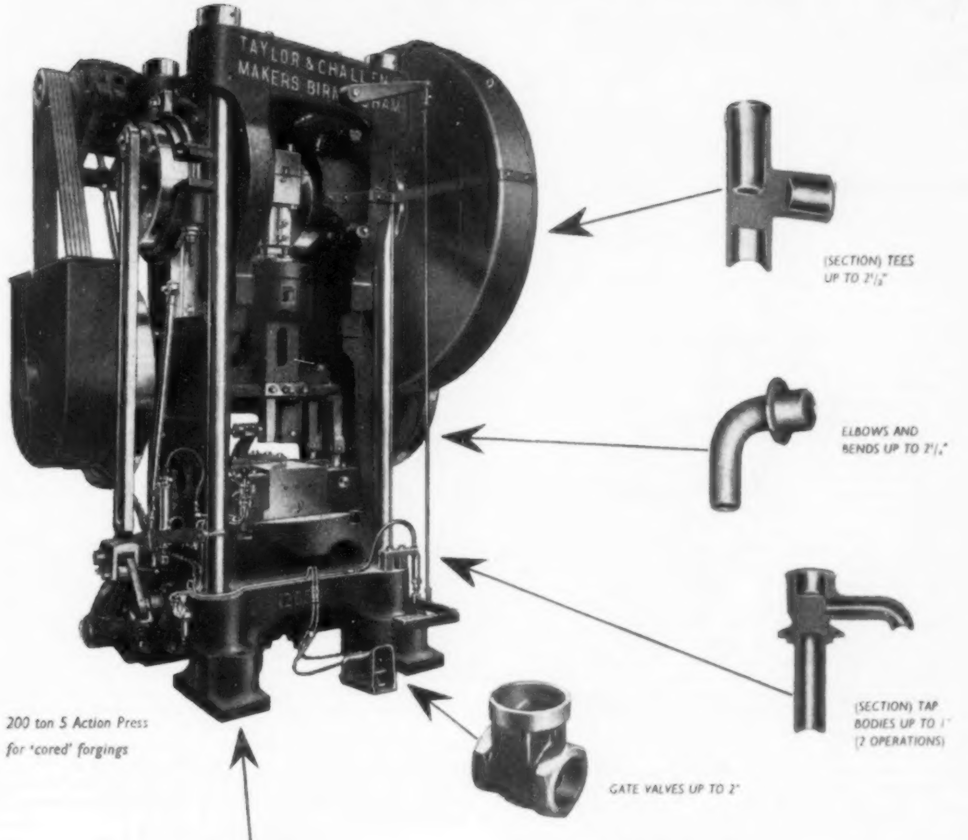
THE Series CRW.4 synchronous resistance welding control unit, designed and manufactured by the Lancashire Electronic Products Ltd. for use with portable gun-welding machines and embodies the following features: fully synchronous timing throughout, controlled timing of "squeeze," "weld," "hold," and "off" periods, each interval being independently adjustable from 1-100 cycles in one cycle steps, single repetitive spot operations, stepless power control with 30 : 1 range of weld heat without changing transformer taps, stepless adjustment of "up-slope" power during weld period, electronic contactor designed to accommodate ignitrons of international sizes "A," "B" and "C," suitable for all supply systems from 220 to 500 volts a.c. 50/60 c.p.s. The Series CRW.4 equipment is suitable for the control of all spot or gun welding machines up to 1,200 kVA rating and for wall or gantry mounting. Fig. 3 shows the power chassis being removed.

(*Continued in page* 74)

Fig. 3.—Gun-welding control



HOT BRASS FORGING PRESSES



200 ton 5 Action Press for 'cored' forgings

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TAYLOR & CHALLEN LTD *BIRMINGHAM 19*

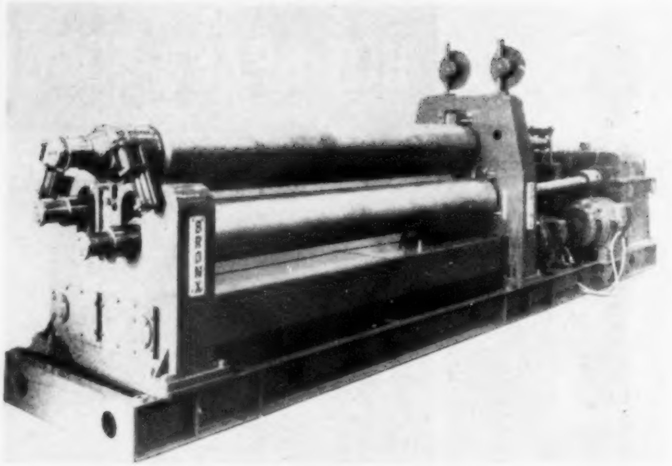


Fig. 4.—Plate bending rolls with bottom driven rolls adjustable

Plate Bending Rolls

THE Bronx Engineering Co. Ltd. of Lye, Stourbridge, have recently introduced a range of bending rolls of the pinch/pyramid type in which the rolls are arranged in pyramid form, but instead of the top idle roll being provided with vertical adjustment, the two bottom driven rolls are adjustable and can be moved vertically either independently or simultaneously; to allow this vertical movement, the two bottom rolls are driven through universal couplings from the main gear box. With this design, plate can be rolled with the same simplicity as in the case of the normal 3-roll pyramid type of machine but in addition, both long edges of the plate can be pre-formed prior to rolling without taking the plate out of the machine as is necessary in the case of a standard 3-roll initial pinch bending roll. Fig. 4 shows a "Bronx" Series PPP. 410 pinch/pyramid rolls with a capacity for pre-bending and rolling mild-steel plate 10 ft. in width by ½ in. thick; the machine has roll necks extending outside the housings on the swing down end and various types of roll can be fitted to these extensions for bending angles and other sections. The top roll is balanced from the drive end and the bearing housing swings down at the non-drive end to facilitate the removal of completed cylinders; both of these operations are carried out pneumatically and the controls are combined so that only one movement is necessary by the machine operator. Large indicator dials are fitted at the drive end to register the movement of the bottom rolls and electric limit switches are fitted to prevent damage to the machine should the bottom rolls be accidently over-run either up or down.

Multi-Slide Stamping Machine

THE U.S. Tool Co., Inc., Ampere, East Orange, New Jersey, U.S.A., have recently added to their range of multi-slide machines for the production of intricate formed stampings by the introduction of the No. 36D duplex machine, Fig. 5. Sole United Kingdom selling agents for U.S. Tool Company products are Rockwell Machine Tool Co. Ltd., Welsh Harp, Edgware Road, London, N.W.2.

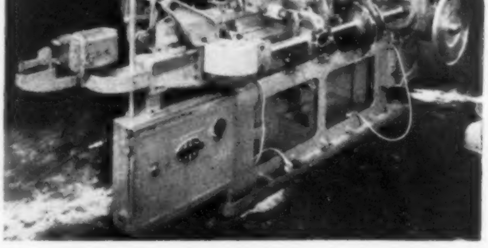
Developed from the standard No. 35 multi-slide machine, which is manufactured under licence in this country, the No. 36D is in effect a double ended machine. Strip material is fed in at both ends, this arrangement being suited to the manufacture of assemblies which could include two formed stampings made and assembled in the machine, or two stampings made in the machine and assembled with a prefabricated hopper fed member. Alternatively, the machine can be used for producing two stampings not requiring assembly or one component only in the manner of a standard multi-slide machine.

The No. 36D will handle stock up to 3 in. wide by approximately $\frac{3}{32}$ in. thick, the feed length from each end being separately adjustable up to a maximum of 6 in. Machines are supplied with a stock straightener, slide feed mechanism and stock check at each end, a 25-ton capacity die head in each of the two sections, one four slide forming position and a common stripper unit with double motion. The machine is powered by a 7½-h.p. motor through a variable-speed drive unit and an air-operated clutch and brake unit is incorporated. The main lubrication system is automatic.

In addition to the standard equipment, each section of the machine can be equipped with an extra die head, a cut-off slide and a rear auxiliary slide. Since the machine is of the usual "U.S." symmetrical design, die heads can be actuated by either the front or rear drive shaft. The basic design plus the auxiliary units available results in a machine with exceptional versatility for the production of formed metal stampings and assemblies comprising two such stampings.

(*Continued in page* 76)

Fig. 5.—Multi-slide stamping machine



Automatic Roll-feed Press

FIG. 6 illustrates the "Autogil" No. 5 press manufactured by the Wallis Engineering Co., 399 Warwick Road, Birmingham, 11, which will produce pressings at the rate of 120 pieces per minute or will automatically measure and cut pieces from strip or coiled material to any length up to one mile. The end of each piece can be cut and shaped or cut and punched simultaneously. Simple holes of up to $\frac{3}{4}$ in. diameter or profiles, can be punched and pierced in approximately $\frac{1}{16}$ in. mild steel or in non-metallic materials up to $\frac{1}{4}$ in. thick.

Fig. 6.—Automatic roll-feed press

Welding Platens

COURTBURN POSITIONERS LTD. of Stanley Works, Kempston Hardwick, Bedford, have increased their range of platens to include all sizes from 4 ft. by 2 ft. by 4 in. to large extra heavy type 10 ft. by 5 ft. by 6 in. and to cater for a demand for a lower priced platen, have designed and manufactured two new platens, size 6 ft. by 3 ft. by 6 in. and 8 ft. by 4 ft. by 6 in.; the overall weight has been reduced but the strength is ensured by an added longitudinal rib to the former platen and a cross rib to the latter size.

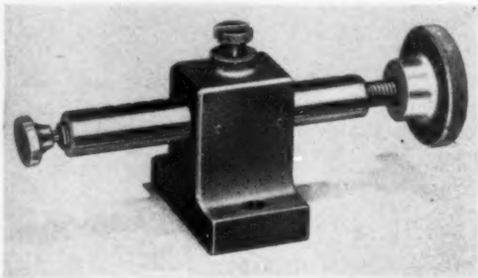
Joint Breaker

ALLWEATHER PAINTS LTD., 36 Great Queen Street, London, W.C.2, have produced a liquid formulation, "Pitan Joint Breaker," specially compounded to ensure easy, safe, and speedy disconnection and removal of flanges, couplings, pipes, unions, sockets, ferrules, castings, fabrications, etc., by the emulsification of the jointing compound uniting their faces, surfaces or threads, in a simple way which removes the danger of destruction or damage inherent in the normal method of forcing or breaking the joint. The Pitan Joint Breaker is of medium viscosity, and is prepared ready for use and needs no dilution or other attention. The method of application is simply by pouring or brushing on and disturbed threads, flanges or mating surfaces can be wiped clean of all sealing compound without scraping or mutilation of any kind.

Ratchet Piston Clamp

SPEED TOOLS LTD. of Vereker House, Gresse Street, London, W.1. have produced a ratchet piston type of clamp in two sizes, the smaller of which is shown in Fig. 7, designed for use where fast clamping is required with a straight push action on to the work to be held, or where it is desired to clamp through holes, into deep recesses or over lips and obstructions. The new clamps combine the advantages of screw operation with instantaneous coarse adjustment. The coarse adjustment is provided by the ratchet teeth which are spaced $\frac{3}{16}$ in. apart and fine adjustment by the 16 t.p.i. screw which has a range of adjustment in the barrel of $\frac{3}{4}$ in., although normally only a fraction of this is required for final clamping, not more than three turns of the handwheel being required to give fixing and locking. In practice, it has been found that most types of work can be loaded and clamped in two seconds.

Fig. 7.—Fine adjustment ratchet clamp



Terylene Industrial Clothing

WILSON BROTHERS of Epsom Ltd., Willbro Works, Epsom, Surrey, have just commenced the manufacture of Terylene clothing for the chemical and other industries where working conditions include acid-laden atmospheres. Terylene protective clothing has undergone stringent tests at the works of I.C.I. Metals division at Witton and after two-years' wear in acid-laden atmosphere, Terylene boiler suits, it is claimed, have shown little more than normal wear, whereas cotton clothing was degraded after only four-weeks' wear. A large electroplating works has changed over to Terylene industrial clothing after a four-years' trial, after confirming that garments lasted three or four years against only one month's wear with cotton garments.

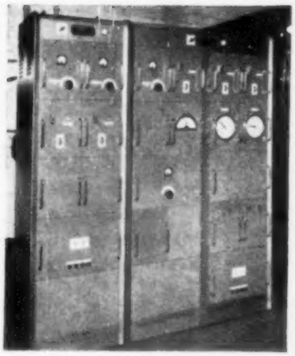
The results of a complete acid exposure test on 100 per cent Terylene overall cloth and 100 per cent cotton drill material are given below. The strips of fabric were immersed for one hour at 30° C. in various types and constituents of acids.

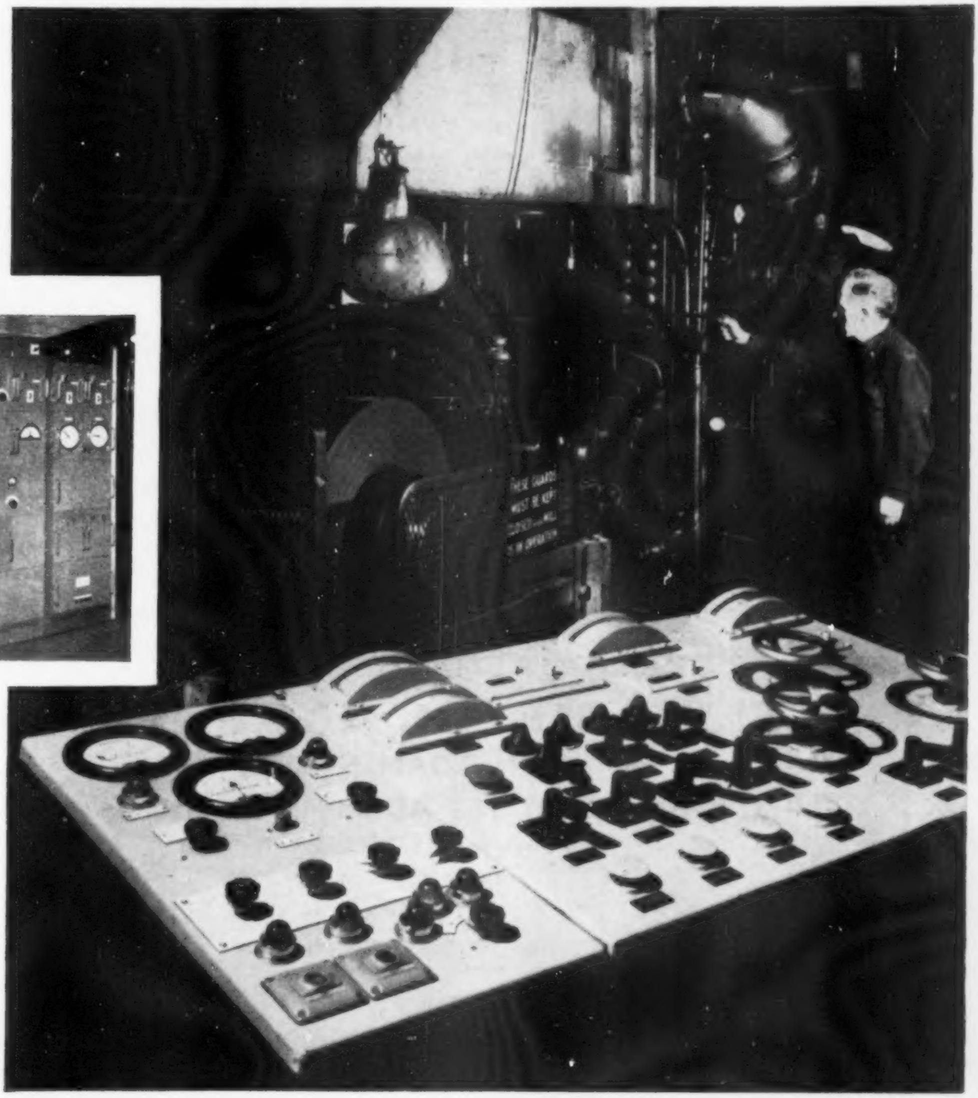
Acids	*Percentage Concentration* (w/w)	*Percentage loss in strength after 1 hour steep at* 30° C. *Cotton*	*Terylene*
Sulphuric	10	5	0
	30	27	0
	50	62	0
Hydrochloric	10	5	0
	36.5	100	0
Nitric	10	0	0
	30	7	0
	50	38	0
	70	Fabric shrunk	
Phosphoric	88	30	0

GKN + AGC

GUEST, KEEN & NETTLEFOLDS ADOPT AUTOMATIC GAUGE CONTROL

by DAVY-UNITED





The 10½″ and 28″ x 24″ Reversing Cold Strip Mill in the Castle Works, Cardiff, of Guest, Keen & Nettlefolds (South Wales) Limited, on which the Davy-United Gaugemeter system of Automatic Gauge Control has recently been installed.

DAVY-UNITED

DAVY AND UNITED INSTRUMENTS LIMITED, DARNALL WORKS, SHEFFIELD 9

DAVY-ASHMORE GROUP

SUBSCRIPTION ORDER FORM

SHEET METAL INDUSTRIES

JOHN ADAM HOUSE,

17-19, JOHN ADAM ST., ADELPHI, LONDON, W.C.2

Telephone: TRAFALGAR 6171

Please send SHEET METAL INDUSTRIES to the address given below, for which 30/- is enclosed in payment of One Year's Subscription.

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Address..

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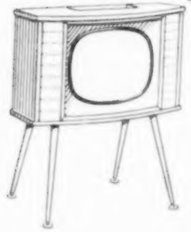
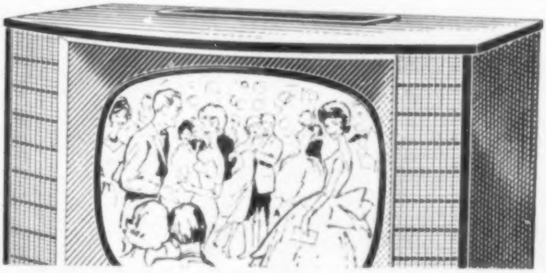
Date..

Cheques and Post Office Orders to be made payable to: Industrial Newspapers (Fuel and Metallurgical) Ltd.





CLASSIFIED ADVERTISEMENTS

PREPAID RATES: TYPE ADVERTISEMENTS (no blocks) 2/- per line or 24/- per single column inch (12 lines per inch). Minimum charge 8/- (4 lines). Average number of words per line 7.

DISPLAY ADVERTISEMENTS (with or without blocks) per single column inch (width 2 ins.) 12 insertions £1. 10. 0. each, 6 insertions £1. 13. 0. each, single insertion £2. 0. 0. (pro rata larger spaces). BOX NUMBER 2/6 including postage of replies.

Advertisements (accompanied by a remittance) and REPLIES TO BOX NUMBERS should be addressed to the Classified Advertisement Manager, "Sheet Metal Industries," John Adam House, 17-19, John Adam Street, Adelphi, London, W.C.2. Telephone: TRAfalgar 6171.

MACHINERY and MATERIALS WANTED

TIN BOX Plant and Presses required suitable for round and irregular containers manufacture.—Modern Packages Ltd., Phoenix Works, Uxbridge, Middlesex.

POWER PRESS WANTED. 250-300 ton, double crank, about 15 in. stroke, 50 in. to 72 in. between columns, with air cushion. Good price paid for serviceable Press. Box No. 979, "Sheet Metal Industries," 17-19, John Adam Street, London, W.C.2.

MACHINES (SECOND-HAND), in good working condition, wanted. 1-Wire Straightening and Cutting-Off Machine, capacity 6G-16G, 0-12 ft. 1-48 in. Press Brake and 1-72 in. Press Brake.—Details to George H. Elt, Ltd., Eltex Works, Bromyard Road, Worcester. Telephone No.: Worcester 27377.

MACHINERY and MATERIALS FOR SALE

TWO BLISS ROLL HEMMING MACHINES for sale. Eight rollers arranged in four pairs and two tuck-in wheels. On cast iron legs. At present tooled for rolling ¼ in. wide hem on two edges of four-gallon can body blanks 13¾ in. wide. Motor drive 220/440/3/50. F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1; or 41, Water Street, Birmingham 3.

30 IN. x 36 in. Two-High Cold Reversing Mill by Davy & United; motorised screw down; power driven roller tables; 500 h.p. drive. 24 in. x 36 in. Two-High Reversing Mill by Davy & United; automatic preset screw down gear; power plant gearbox and 300 h.p. motor drive with power driven roller tables. 24 in. x 60 in. Two-High Cold Sheet Mill by Krupp with Double Helical Pinion stand. 21 in. x 39 in. Two-High Mills by Taylor & Farley; two Hot and one Cold Mill with 300 h.p. gearbox drive.—Reed Brothers (Engineering), Ltd., Replant Works, Woolwich Industrial Estate, London, S.E.18. Tel. Woolwich 7611 (6 lines).

TWO BLISS NO. 805 8-STATION MOTORISED CAN TESTING MACHINES for sale. At present set up for 4-gallon cans 9¼ in. x 9¼ in. x 13¾ in. high. Inclined feed track to testing chambers. Air pressure test of 5 lb. per sq. in. Leaky cans automatically rejected. Arranged motor drive 400/3/50. Production rate 18 cans per minute. F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham 3.

TWO DOUBLE ACTION HYDRAULIC PRESSES FOR SALE. British Clearing DH 55-35-30. Pressure: punch 55 tons, blankholder, 35 tons; both rams 90 tons. Steel frame. Both strokes adjustable, punch up to 8 in. Blankholder up to 4 in. Between uprights 32 in. Complete with cushioned bed, all self-contained hydraulic equipment for motor drive, 400/440/3/50. Photographs, etc., from F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1. EUS 5000; or 41, Water Street, Birmingham 3. CENtral 7606.

MACHINERY and MATERIALS FOR SALE—*contd.*

TWW

BLISS 80½ single action double sided Power Press, 1,000 tons cap., stroke 20 in., bed 47 in. x 60½ in., 5 s.p.m. motorised.

BLISS Model 305½ double sided, single action Power Press, 110 tons cap., 12 in. stroke, bed 26 in. x 26 in., motorised 400/3/50.

BRITISH CLEARING Model 90-6 Mechanical Press Brake, 6 ft. x ¼ in. M.S. between frames, motorised 400/3/50.

RHODES 6 ft. x ¼ in. mechanical Overcrank Guillotine, motorised 400/440/3/50.

THOS. W. WARD LTD.
ALBION WORKS - SHEFFIELD
Phone: 26311 Ext. 371

Remember - - Wards might have it!

VITREOUS ENAMELLING PLANT

2 MUFFLE HANGING FURNACES, Incandescent Heat Co., oil converted to gas fired. 14 ft. 6 in. x 5 ft. 7 in. deep x 2 ft. 10 in. wide overall. Complete with chargers, adjacent self-heated drying chambers, recording and controlling equipment.

MUFFLE FLAT FIRING FURNACE. Incandescent Heat Co., gas fired. 7 ft. 6 in. x 3 ft. 6 in. wide x 2 ft. 9 in. deep overall. Complete with charger, recording and controlling equipment.

PEBBLE MILLS. Steele and Cowlishaw. One each 5 cwt., 200 lb., 63 lb. Four 143 lb.

DOUBLE JAR MILL. 6 lb. each.

Tilghman ROOM SHOTBLAST. Hand rotated table 6 ft. dia. with 4 ft. high division. Room 7 ft. sq. x 8 ft. high. Cyclone.

Tilghman WHEELABRATOR with Steel Conveyor 3 ft. 3 in. x 3 ft. dia. 4 speeds and reverse.

Tilghman SHOTBLAST BARREL converted to cabinet 2 ft. 6 in. x 1 ft. 11 in. floor. Cyclone.

Tilghman D.A.6 DUST ARRESTER with Blowback Screen and Fan.

Jackman CABINET SHOTBLAST. 3 ft. 3 in. x 2 ft. 6 in. floor. Combined Dust Unit.

Olympia MOTORISED SIFTER, 1 ft. dia.

ENTWISLE AND KENYON LIMITED,
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BLISS NO. 319 AUTOMATIC TRIMMING, BEADING & THREAD ROLLING MACHINE for sale. Capacity ½ in. to 4 in. diameter and up to 1 in. long. Chute feed. Arranged motor drive 400/3/50. F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham 3.

TAYLOR & CHALLEN NO. 6 G.D.P. DOUBLE SIDED DOUBLE ACTION TOGGLE DRAWING PRESS. Punch stroke 19 in. Blankholder stroke 10½ in. Between side frames 38½ in. Blankholder 30 in. diameter. Hole in blankholder 23½ in. diameter. Motor drive 400/440/3/50. Weight about 17 tons. F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham 3.

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IF you have spare capacity for spinnings up to 30 in. in diameter, presswork, or the assembly and finishing of small components, we should be pleased to hear from you.—Send details to Box 981, "Sheet Metal Industries," 17-19, John Adam Street, London, W.C.2.

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GENERAL MANAGER REQUIRED

First class general Manager required for shearing works in the London area. Experience in regrading and shearing of prime and secondary Steel Sheets and Plates essential. Ability to introduce business an advantage. Remuneration no problem for right individual. Housing arrangements possible. Write in confidence with full details of experience to **Box No. 983, "Sheet Metal Industries," 17-19, John Adam Street, London, W.C.2.**

BOOKS

TIN BOX Engineers and others concerned with sheet metal production problems should have a copy of "Tin Box Manufacture," by J. W. Langton, M.B.E., B.Sc., M.I.Mech.E., obtainable from Canning Publications, 14, Coleman Street, London, E.C.2, price 31s. 6d. post free. (Leaflet free.)

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PRESS WORK of all descriptions carried out. Deep Drawing up to 15 in. deep, Blanking and Forming up to 80 tons.—Wades (Halifax), Ltd., Arden Works, Fenton Road, Halifax.

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PRODUCTION capacity available for High Class Press Tools, Jigs, Fixtures, Machining and Sheet Metal Prototypes, etc. 'Phone Wolverhampton 31584 or write The Newlands Engineering Co., Ltd., Victoria Road, Wednesfield, Wolverhampton.

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FABRICATION, WELDING AND X-RAY INSPECTION, PRESSINGS AND MACHINED PARTS

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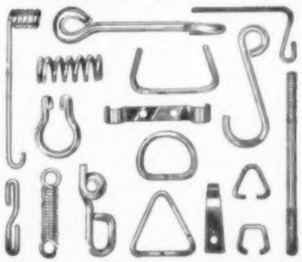

W. B. & U. ATKINSON, LTD.
Rosse Street Works, Shipley, Yorks.

MAY we quote you for Metal Spinnings in all metals up to 36 in. blank. Specialists to the plumbing trade. Wilkins and Wilkinson, Whitwell Green Lane, Elland, Yorks.

WE specialise in slitting your own material in widths from ¼ in.-4 in. and gauges from .010 in.-.064 in. and would welcome enquiries for all types of material. Quick delivery guaranteed.
ALEX J. CHEETHAM LIMITED.
Dob Lane Mill, Morton Street, Failsworth, Manchester.

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from stock or customers' own material. £2/£5 per ton commission paid on receipt of order. Guillotines to cut 400 tons per month. All business strictly confidential. **Box No. 987, "Sheet Metal Industries," 17-19, John Adam Street, London, W.C.2.**

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for Hand and Power Presses up to 70 tons single action, and 90 tons double action. Old Hill, Staffordshire area.
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VITREOUS ENAMELLING

Capacity available for Sheet Metal Parts

ALSO FACILITIES FOR FABRICATION

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METAL SPINNING OUR SPECIALITY
UP TO 9 ft. DIAMETER
(HYDRAULIC AND FLOW TURNING)
POWER PRESSWORK to 250-ton capacity, including Hydraulic.
GENERAL SHEET METAL WORK, ARGON, ARC & OXY-ACETYLENE WELDING
DEEP DRAWN PRESSINGS
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JANUARY 1961

(*denotes pages numbered in editorial sequence)

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Sheet Metal Industries

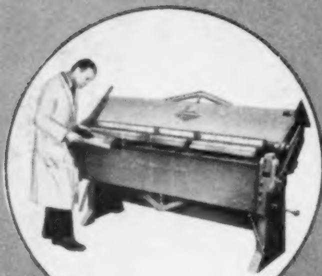
The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

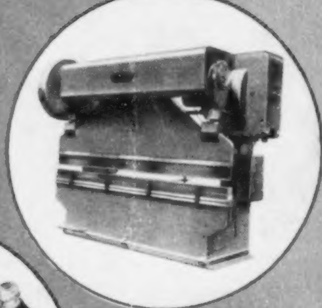
VOL. 38 : No. 405 JANUARY 1961 PRICE 2/6

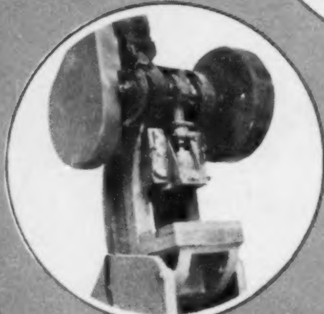
Besco Machines *are good* For Sheet Metal !

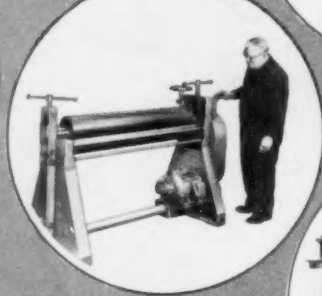
For years and years,

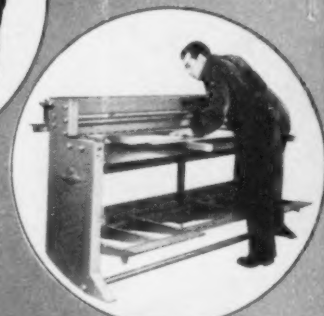
FJE Besco machines have cut and shaped sheet metal for a variety of useful finished forms . . . from ducting to chick brooders: aircraft to refrigerators: ships to furniture . . . and still they cut and shape sheet metal.











FJE Besco guillotines and shears cut energetically and accurately through ferrous and non-ferrous sheets: press brakes, folders, angle benders and bending rollers form, bend and curve the panels, pans, boxes and mouldings.

FJE Besco swages and wiring machines bead and turn edges for ornamental strength and safety: nibbling machines precisely bite along the edges of intricately shaped templates.

FJE Besco flangers pound the edges of metal blanks and lift the edges high, square and even: presses pierce and stamp endless components in a flood of production.

Yes, indeed, Besco machines are good for sheet metal . . . without them, sheet metal would remain—well, just sheet metal!

Excellent terms; monthly account, hire purchase, or the FJE Machine Hire Plan.

F.J. Edwards Ltd

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